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CATALOG OF DOUBLE LUNAR SWINGBY ORBITS FOR EXPLORING THE EARTH'S GEOMAGNETIC TAIL

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Prepared For

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Goddard Space Flight Center
Greenbelt, Maryland

CONTRACT NAS 5-24300
Task Assignment 803

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CSC/TM-80/6322

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Prepared for

GODDARD SPACE FLIGHT CENTER

By

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Under

Contract NAS 5-24300
Task Assignment 803

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ABSTRACT

Forty-three orbits, which are periodic in geocentric reference frames rotating at lunar and at solar rates, have been found using a patched-conic technique. The different orbits provide coverage of different parts of the distant geomagnetic tail. Included in this memorandum is an introduction, the parameters for 43 Sun-synchronous double lunar swingby orbits, and plots of the Sun-synchronous double lunar swingby orbits.

TABLE OF CONTENTS

Section 1 - Introduction. 1-1

Section 2 - Parameters for 43 Sun-Synchronous Double Lunar Swingby Orbits 2-1

Section 3 - Plots for Sun-Synchronous Double Lunar Swingby Orbits 3-1

LIST OF ILLUSTRATIONS

Figure

3-1 Double Lunar Swingby Orbit - [1,1,1] Class 3-2
3-2 Double Lunar Swingby Orbit - [1,1,2] Class 3-3
3-3 Double Lunar Swingby Orbit - [1,1,3] Class 3-4
3-4 Double Lunar Swingby Orbit - [2,3,1] Class 3-5
3-5 Double Lunar Swingby Orbit - [2,3,2] Class 3-6
3-6 Double Lunar Swingby Orbit - [2,3,3] Class 3-7
3-7 Double Lunar Swingby Orbit - [2,4,1] Class 3-8
3-8 Double Lunar Swingby Orbit - [2,4,2] Class 3-9
3-9 Double Lunar Swingby Orbit - [2,4,3] Class 3-10
3-10 Double Lunar Swingby Orbit - [3,4,1] Class 3-11
3-11 Double Lunar Swingby Orbit - [3,4,2] Class 3-12
3-12 Double Lunar Swingby Orbit - [3,4,3] Class 3-13
3-13 Double Lunar Swingby Orbit - [3,5,1] Class 3-14
3-14 Double Lunar Swingby Orbit - [3,5,2] Class 3-15
3-15 Double Lunar Swingby Orbit - [3,5,3] Class 3-16
3-16 Double Lunar Swingby Orbit - [3,5,4] Class 3-17
3-17 Double Lunar Swingby Orbit - [3,6,1] Class 3-18
3-18 Double Lunar Swingby Orbit - [3,6,2] Class 3-19
3-19 Double Lunar Swingby Orbit - [3,6,3] Class 3-20
3-20 Double Lunar Swingby Orbit - [3,7,1] Class 3-21
3-21 Double Lunar Swingby Orbit - [3,7,2] Class 3-22
3-22 Double Lunar Swingby Orbit - [3,7,3] Class 3-23
3-23 Double Lunar Swingby Orbit - [4,8,1] Class 3-24

LIST OF ILLUSTRATIONS (Cont'd)

Figure

3-24 Double Lunar Swingby Orbit - [4,8,2] Class 3-25
3-25 Double Lunar Swingby Orbit - [4,8,3] Class 3-26
3-26 Double Lunar Swingby Orbit - [4,9,1] Class 3-27
3-27 Double Lunar Swingby Orbit - [4,9,2] Class 3-28
3-28 Double Lunar Swingby Orbit - [4,9,3] Class 3-29
3-29 Double Lunar Swingby Orbit - [5,10,1] Class 3-30
3-30 Double Lunar Swingby Orbit - [5,10,2] Class 3-31
3-31 Double Lunar Swingby Orbit - [5,10,3] Class 3-32
3-32 Double Lunar Swingby Orbit - [5,11,1] Class 3-33
3-33 Double Lunar Swingby Orbit - [5,11,2] Class 3-34
3-34 Double Lunar Swingby Orbit - [1,1,2,1] Class 3-35
3-35 Double Lunar Swingby Orbit - [1,1,3,1] Class 3-36
3-36 Double Lunar Swingby Orbit - [1,1,4,1] Class 3-37
3-37 Double Lunar Swingby Orbit - [1,1,5,1] Class 3-38
3-38 Double Lunar Swingby Orbit - [1,1,4,2] Class 3-39
3-39 Double Lunar Swingby Orbit - [1,1,5,2] Class 3-40
3-40 Double Lunar Swingby Orbit - [2,4,2,1] Class 3-41
3-41 Double Lunar Swingby Orbit - [2,4,3,1] Class 3-42
3-42 Double Lunar Swingby Orbit - [3,6,2,1] Class 3-43
3-43 Double Lunar Swingby Orbit - [3,6,4,1] Class 3-44

SECTION 1 - INTRODUCTION

A new trajectory technique for mapping the geomagnetic tail is described in Reference 1. The apogees of the orbit are alternately raised and lowered by moderately close approaches to the moon. The lunar swingby distance and other orbital parameters can be varied until the apogees remain in the antisolar direction. Consequently, the selected orbits are periodic in coordinate systems rotating with both lunar and solar rates.

Computer programs were written to find and plot these periodic orbits. A patched conic technique was used in conjunction with zero sphere-of-influence methods similar to those described in Reference 2. The Moon's orbit was assumed to be circular with a radius of 384,399 kilometers. All orbits described here were assumed to be in the lunar orbital plane. When the Earth-centered elliptical orbit of the spacecraft crossed the lunar orbit, it was bent to take into account the attraction by the Moon. The new (bent) velocity vector and the radius vector at the lunar orbit crossing were used to calculate a new Earth-centered elliptical orbit. The lunar swingby distance is related to the bend angle by a formula given in Reference 2. The Moon was assumed to be at the swingby distance from the spacecraft when the latter crossed the lunar orbit.

A coarse-scan computer program varies the bend angle at the lunar orbit until the rate of advance of the line of apsides equals the solar rate (i.e., the rate of revolution of the earth about the Sun) of $0^{\circ}.9856$/day. The timing mismatches of the preceding and following lunar swingbys are then calculated. Many cases are computed this way for specified ranges of initial orbit perigee

and apogee distances, and results are printed only for those cases where the timing mismatches are smaller than specified tolerances.

Another computer program, basically similar to the coarse-scan program, starts with initial conditions near a periodic orbit, then uses Newton-Raphson iterations to vary the initial orbit parameters until the preceding and following lunar swingby timing mismatches are less than 0.0001 day. The periodic orbit is then considered found, and a plot subroutine is called. The plot subroutine generates an ephemeris for one complete cycle of the orbit, transforms all of the computed points into a geocentric system rotating at the solar rate, writes these data onto magnetic tape, and produces a printer plot of the orbit.

Software designed to generate 16mm movies of double lunar swingby orbits, using input ephemeris tape data like those described above, is described in Reference 3. This software was modified to produce single-frame plots and to add tick marks to the orbit at daily intervals. The tick marks are perpendicular to the orbit and face away from the local center of curvature of the path.

Several (actually, an infinite number) different types of Sun-synchronous double lunar swingby orbits exist, depending on the number of months spent in the small (inner) and large (outer) ellipse segments and depending on the number of complete circuits per cycle in the inner and outer segments. A three-dimensional classification scheme was described in Reference 1. That scheme is used here, but expanded to include a fourth parameter. Hence, a given periodic orbit is specified by four numbers, [A, B, C, D], which have the following meanings.

A: Approximate number of months between lunar swingbys in the inner segment.

B: Number of complete circuits (apogees) in the inner segment.

C: Approximate number of months between lunar swingbys in the outer segment.

D: Number of complete circuits (perigees) in the outer segment.

The quantity A+C synodic months (one synodic month = 29.5306 days) is the period of the orbit (i.e., the time from one lunar swingby until the next lunar swingby at the same position in the solar rotating frame). The time spent in the inner segment is a few days less than A synodic months, while the time in the outer segment is a corresponding amount of time greater than C synodic months, to allow time for the moon to move from the lower swingby position to the upper swingby position.

For most orbits of interest for studying the magnetosphere, D = 0 and consequently is not given, the orbit being specified by the three numbers [A, B, C]. For D larger than zero, the orbits become butterfly-shaped, with the spacecraft spending most of its time far from the anti-Sun line outside the geomagnetic tail.

Forty-three Sun-synchronous double lunar swingby orbits have been found using the software described above. Our survey includes all possible (28) sun-synchronous orbits of this type with A less than 5, C less than 4, and D equals 0. Orbits do exist for much larger values of C. However, for C greater than 3 and D equals 0, the outer loop extends well beyond the Sun-Earth L_2 libration point, where strong solar perturbations makes our patched-conic

model unrealistic. Although orbits with A greater than 4 are of little interest due to excessive time spent outside the magnetotail, [5, 10, C] and [5, 11, C] orbits do exist and five of these are included in our survey. Ten orbits with D greater than zero have also been found. Since the outer-segment ellipses have periods longer than a month, C is always greater than D.

A table of parameters for the 43 orbits we have found is presented and described in Section 2. Plots of the 43 orbits are given in Section 3.

SECTION 2 - PARAMETERS FOR 43 SUN-SYNCHRONOUS DOUBLE LUNAR SWINGBY ORBITS

Parameters for the orbits found using the software described in Section 1 are listed in Table 2-1. The first four columns give the classification numbers, [A, B, C, D], described in Section 1. The perigee and apogee radii, in km; the orbital eccentricity, e; and the orbital period, all for the inner elliptical (small) orbit segment, are given in the next four columns. The same information, but not the period, is given for the outer (large) orbit segment in the next three columns. The lunar swingby distance, in km, and the amount by which the orbit is bent by the swingby (change in direction of the velocity vector), are listed in the following two columns.

The approximate intermediate (between swingbys) radius of closest approach to the Moon, while the spacecraft is in the inner loop, is given in megameters (units of 10^3 km) in the second to last column, only for A greater than 1. There is no intermediate close approach for A equals 1. The only cases of very close approaches, where large lunar perturbations would destroy our patched-conic orbit, occur for the [4, 9, C] orbits. The intermediate approaches are close enough for significant, but not catastrophic, lunar perturbations for the [2, 3, C] and [3, 5, C] orbits.

The geocentric angle between the spacecraft at the lower lunar swingby, and at its position during the following (upper) swingby, in the solar rotating frames is given in the last column. When this angle has smaller values, the outer loop of the orbit is narrower, providing generally better coverage of the geomagnetic tail.

Table 2-1. Sun-Synchronous Double Lunar Swingby Orbits (1 of 2)

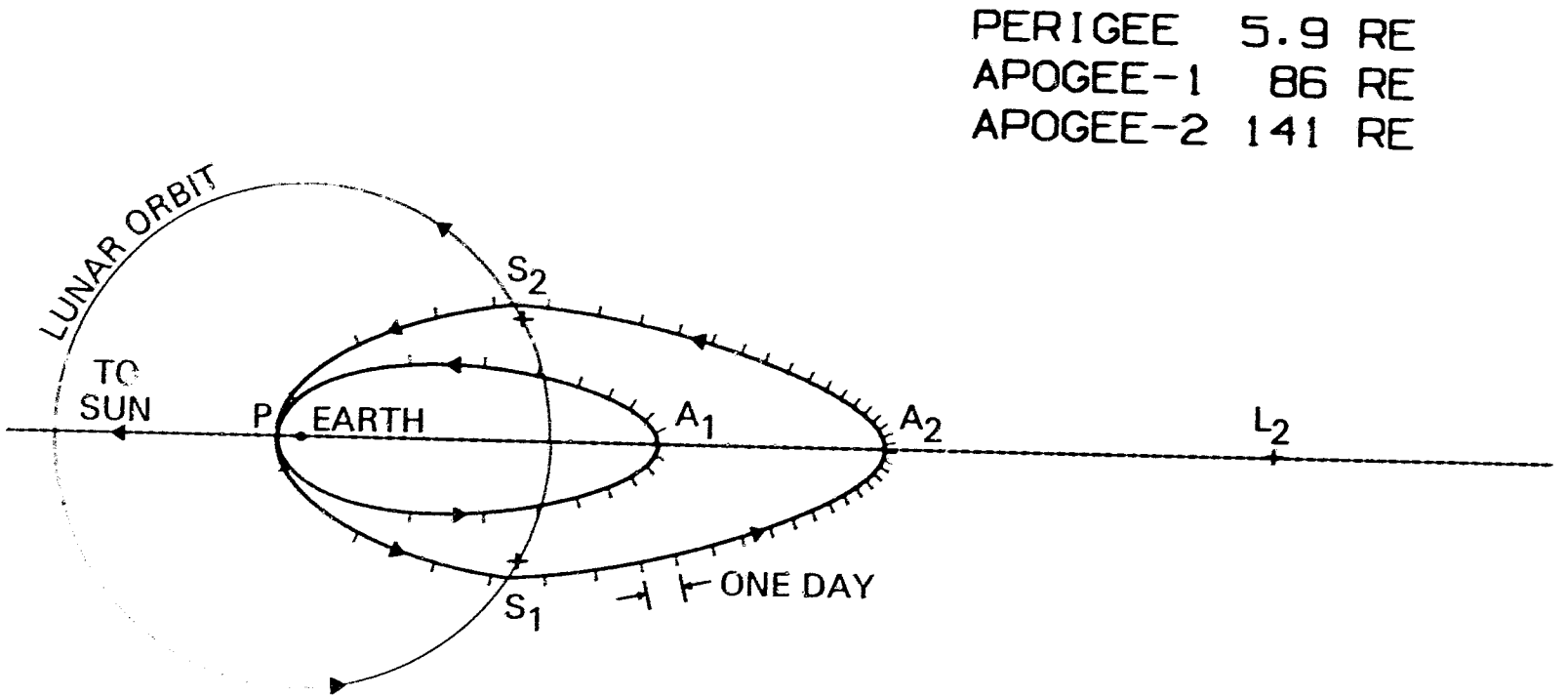
Months in Small Orbit	Complete Small Orbits	Months in Large Orbit	Complete Large Orbits	Small Orbit Segment				Large Orbit Segment			Lunar Swingby Distance (km)	Lunar Bend Angle (Degrees)	Intermediate RCA Moon (10^3 km)	Swingby S/C-Earth-S/C Angle (Degrees)
A	B	C	D	Perigee Radius (km)	Apogee Radius (km)	e	Period (Days)	Perigee Radius (km)	Apogee Radius (km)	e				
1	1	1	0	37,436	549,889	0.873	18.3	104,210	898,915	0.792	27,664	19.4	-	65.3
1	1	2	0	34,414	552,765	0.883	18.3	134,514	1,306,252	0.813	18,104	26.6	-	63.7
1	1	3	0	45,043	525,853	0.842	17.6	182,799	1,642,124	0.800	15,766	33.9	-	66.9
2	3	1	0	38,148	478,881	0.852	15.1	143,080	898,313	0.725	19,936	30.6	94	85.3
2	3	2	0	35,202	482,324	0.864	15.2	173,409	1,296,149	0.764	14,397	37.5	98	84.3
2	3	3	0	45,058	467,503	0.824	14.9	218,719	1,627,326	0.763	13,074	45.2	83	86.5
2	4	1	0	7,296	429,735	0.967	11.8	101,354	905,583	0.799	10,166	41.0	334	63.7
2	4	2	0	6,694	430,381	0.969	11.8	134,079	1,309,548	0.814	7,831	48.1	331	63.3
2	4	3	0	12,042	421,655	0.944	11.6	180,261	1,645,510	0.803	7,207	56.0	352	65.3
3	4	1	0	98,609	468,620	0.652	17.4	234,300	874,797	0.577	32,278	34.6	245	133.3
3	4	2	0	92,819	474,810	0.675	17.4	259,360	1,261,021	0.659	22,502	41.9	232	132.5
3	4	3	0	103,056	461,455	0.635	17.3	294,253	1,587,934	0.687	19,722	51.0	264	132.6
3	5	1	0	53,983	444,972	0.784	14.4	196,325	888,870	0.638	19,489	40.2	103	112.6
3	5	2	0	50,416	448,960	0.798	14.4	224,688	1,277,799	0.701	14,437	47.0	111	112.1
3	5	3	0	58,389	438,084	0.763	14.3	263,280	1,605,960	0.718	12,891	55.7	94	112.4
3	5	4	0	70,043	423,971	0.716	14.1	299,208	1,900,285	0.728	11,797	66.6	73	111.4
3	6	1	0	26,702	420,320	0.881	12.2	168,630	897,171	0.685	12,353	47.7	270	98.0
3	6	2	0	24,645	422,709	0.890	12.2	198,540	1,289,097	0.733	9,536	54.3	265	97.7
3	6	3	0	31,063	414,333	0.861	12.1	238,928	1,619,137	0.743	8,508	63.2	277	97.8
3	7	1	0	10,065	394,217	0.950	10.5	145,433	902,687	0.722	7,175	60.3	208	86.4
3	7	2	0	9,13[illegible]	395,437	0.955	10.5	177,717	1,297,399	0.759	5,760	66.5	202	86.4
3	7	3	0	12,937	389,581	0.936	10.4	217,203	1,630,275	0.765	4,795	77.7	235	85.5

Table 2-1. Sun-Synchronous Double Lunar Swingby Orbits (2 of 2)

Months in Small Orbit	Complete Small Orbits	Months in Large Orbit	Complete Large Orbits	Small Orbit Segment				Large Orbit Segment			Lunar Swingby Distance (km)	Lunar Bend Angle (Degrees)	Intermediate RCA Moon (10^3 km)	Swingby S/C-Earth-S/C Angle (Degrees)
				Perigee Radius (km)	Apogee Radius (km)	e	Period (Days)	Perigee Radius (km)	Apogee Radius (km)	e				
A	B	C	D											
4	8	1	0	45,503	407,151	0.799	12.4	222,048	884,802	0.599	13,404	57.2	232	126.3
4	8	2	0	42,959	409,981	0.810	12.4	250,080	1,268,660	0.671	10,372	63.7	227	126.7
4	8	3	0	48,757	402,914	0.784	12.4	283,526	1,596,596	0.698	8,821	74.3	235	125.2
4	9	1	0	27,536	392,132	0.869	11.1	203,233	891,189	0.629	8,620	67.2	8	116.2
4	9	2	0	25,876	394,144	0.877	11.1	233,218	1,276,674	0.691	6,944	72.9	10	116.8
4	9	3	0	30,020	388,571	0.857	11.0	266,456	1,606,351	0.715	5,494	85.5	4	114.2
5	10	1	0	61,037	395,428	0.733	12.6	263,317	872,890	0.536	13,126	69.6	309	150.3
5	10	2	0	58,758	397,924	0.743	12.6	289,171	1,251,190	0.625	10,164	76.2	201	151.4
5	10	3	0	63,356	392,379	0.722	12.5	315,916	1,579,193	0.667	7,924	88.3	205	148.2
5	11	1	0	42,866	386,116	0.800	11.4	245,968	880,011	0.563	8,070	80.9	172	139.8
5	11	2	0	41,506	387,895	0.807	11.5	274,707	1,258,934	0.642	6,699	85.8	160	141.8
1	1	2	1	75,833	465,542	0.720	16.2	183,551	739,525	0.602	33,590	29.1	-	71.0
1	1	3	1	72,923	467,198	0.730	16.2	212,838	944,603	0.632	24,116	36.2	-	70.1
1	1	4	1	78,129	454,169	0.706	15.8	248,219	1,121,250	0.637	20,335	44.5	-	68.8
1	1	5	1	85,330	437,671	0.674	15.4	281,853	1,282,421	0.640	17,957	54.2	-	66.4
1	1	4	2	94,935	422,043	0.633	15.1	260,910	785,708	0.501	27,354	48.7	-	63.5
1	1	5	2	96,949	415,207	0.621	14.9	287,836	906,506	0.518	22,441	58.1	-	60.7
2	4	2	1	27,859	397,833	0.869	11.3	171,237	750,821	0.629	11,448	56.2	357	65.0
2	4	3	1	27,504	398,062	0.871	11.3	203,195	953,116	0.648	9,195	63.2	181	65.0
3	6	2	1	49,868	389,996	0.773	11.9	224,977	719,441	0.524	12,578	67.8	318	90.9
3	6	4	1	50,937	387,801	0.768	11.8	280,390	1,100,277	0.593	7,873	85.4	337	88.7

SECTION 3 - PLOTS OF SUN-SYNCHRONOUS DOUBLE LUNAR SWINGBY ORBITS

Plots of all of the orbits listed in Table 2-1 are presented in Figures 3-1 to 3-43. The spacecraft orbit is shown with a heavy line, with tick marks at 1-day intervals. The lunar orbit is indicated with a lighter circle, with the Moon's position at the swingbys shown by two crosses. The coordinate system is geocentric, with the axes rotating at the rate of motion of the Earth around the Sun, 0.9856°/day. The Earth-Sun line is the horizontal dashed line. The cross on this axis about 250 Earth radii (RE = 6378 km) behind the Earth is the L_2 libration point of the Sun-Earth system. The distances of the apogees for the inner (A1) and outer (A2) orbit segments, are given in Earth radii. The smaller perigee distances are specified to the nearest tenth of an Earth radius. For the orbits with D greater than 0, inner segment (P1) and outer segment (P2) perigee distances are indicated. Of these, only the closer inner segment perigee distance is specified to the nearest tenth of an Earth radius.



PERILUNE RADIUS AT LUNAR SWINGBYS 27.664 KM

Figure 3-1. DOUBLE LUNAR SWINGBY (MIT - [1,1,1] CLASS

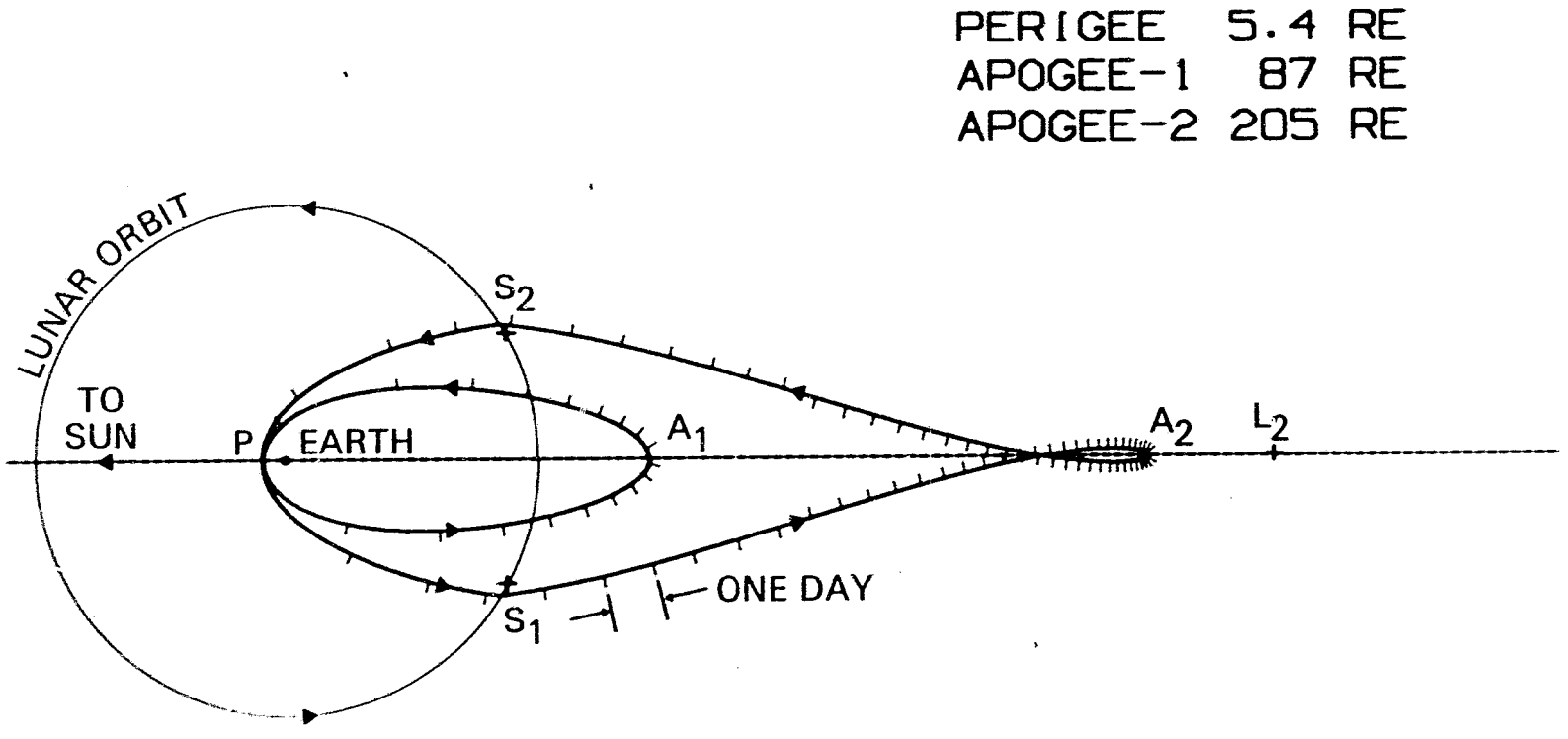


Figure 3-2. DOUBLE LUNAR SWINGBY ORBIT - [1,1,2] CLASS

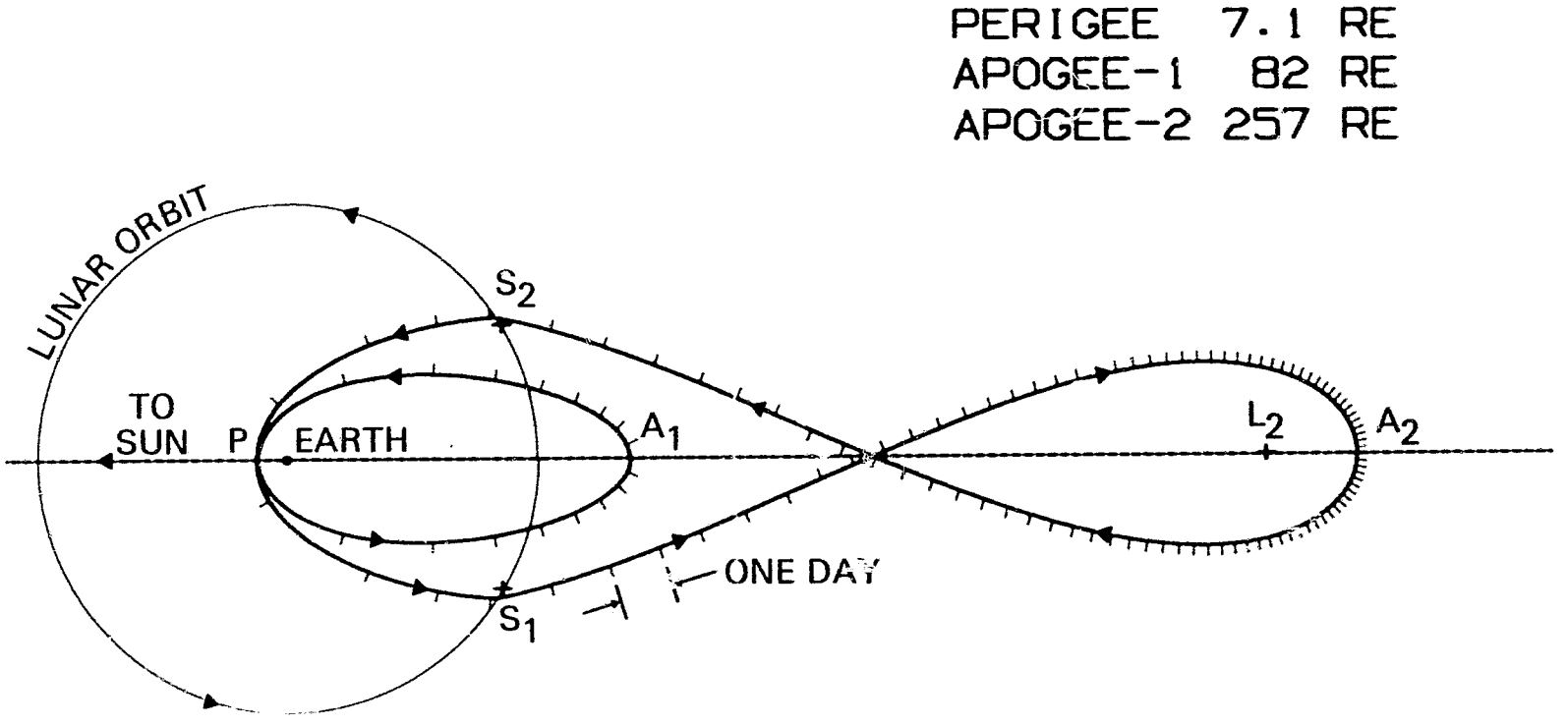


Figure 3-3. DOUBLE LUNAR SWINGBY ORBIT-[1,1,3] CLASS

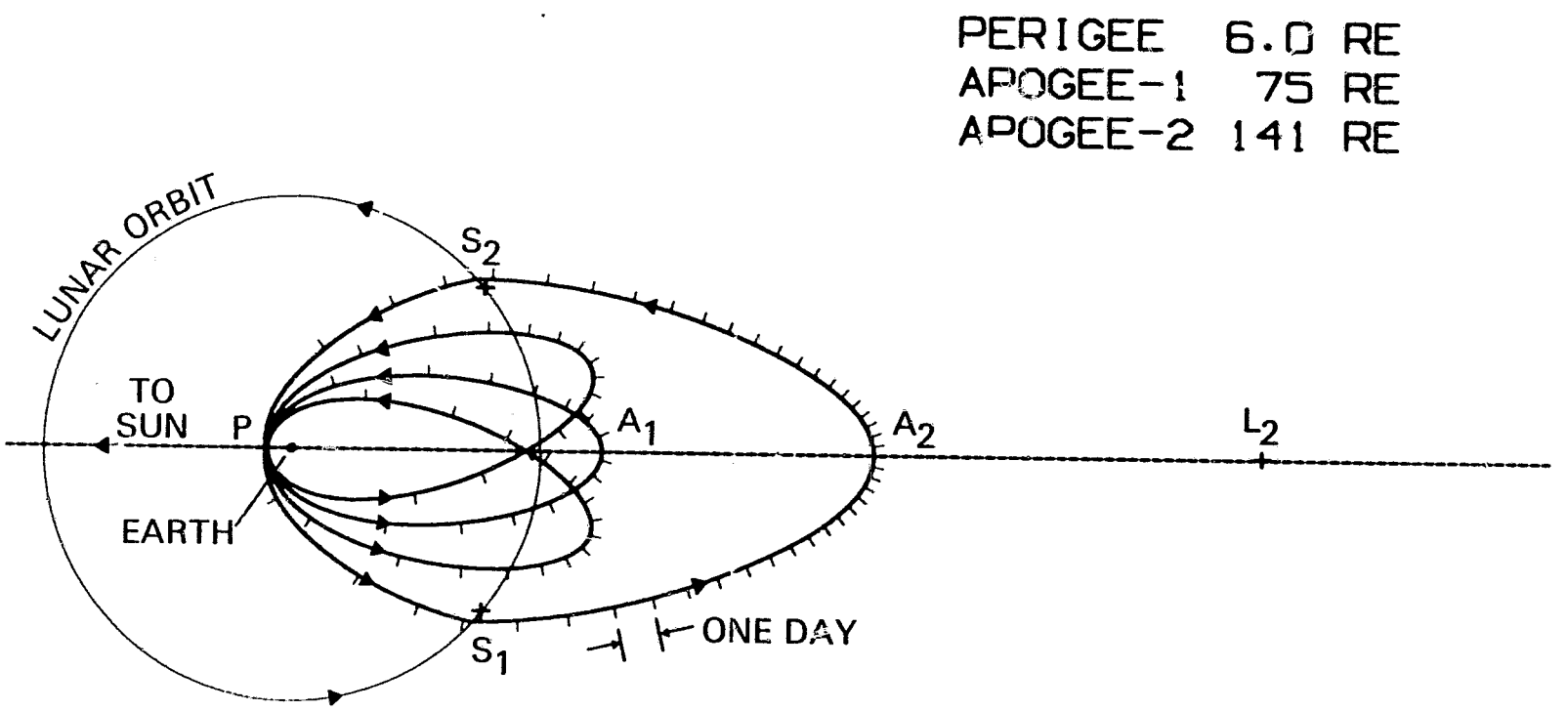
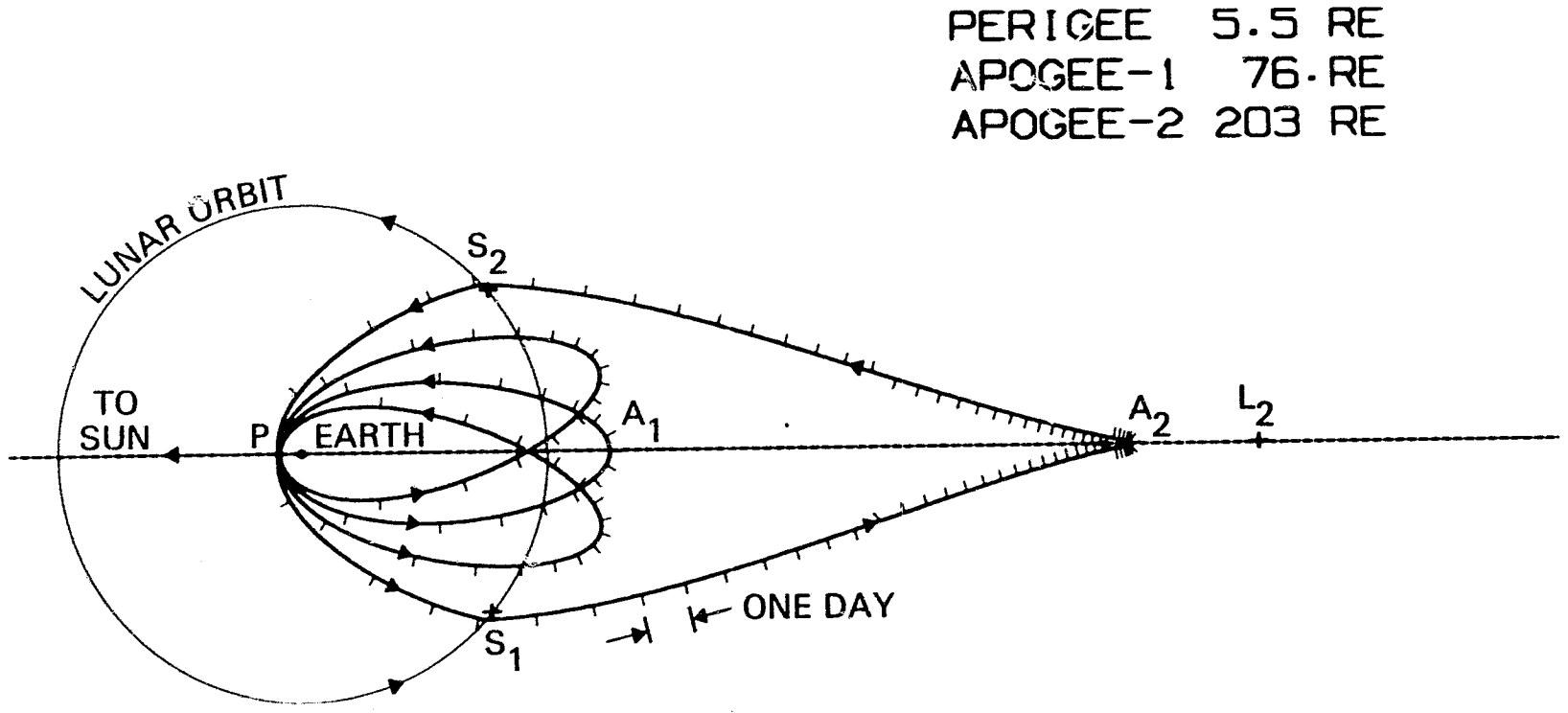
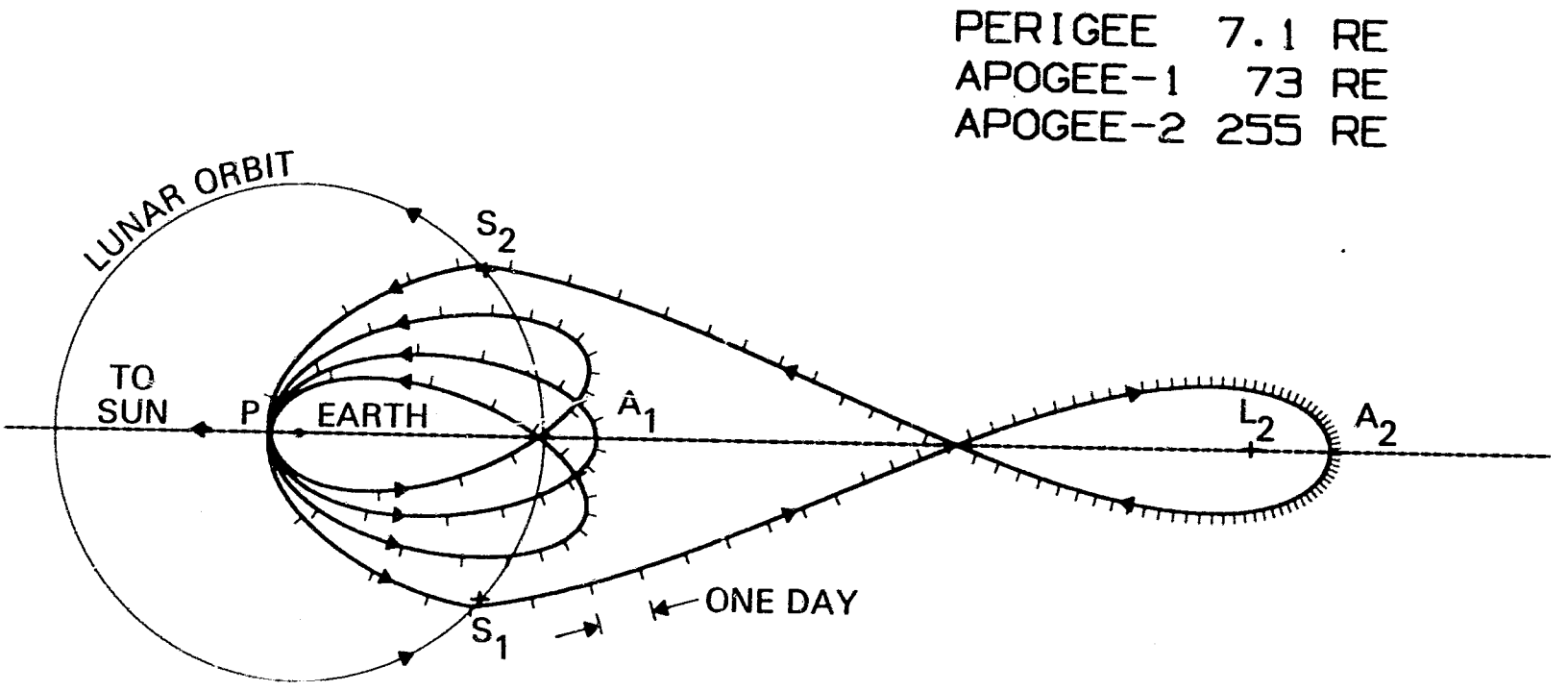


Figure 3-4. DOUBLE LUNAR SWINGBY ORBIT - [2,3,1] CLASS



PERILUNE RADIUS AT LUNAR SWINGBYS 14.397 KM

Figure 3-5. DOUBLE LUNAR SWINGBY ORBIT - [2,3,2] CLASS



PERILUNE RADIUS AT LUNAR SWINGBYS 13.074 KM

Figure 3-6. DOUBLE LUNAR SWINGBY ORBIT - [2,3,3] CLASS

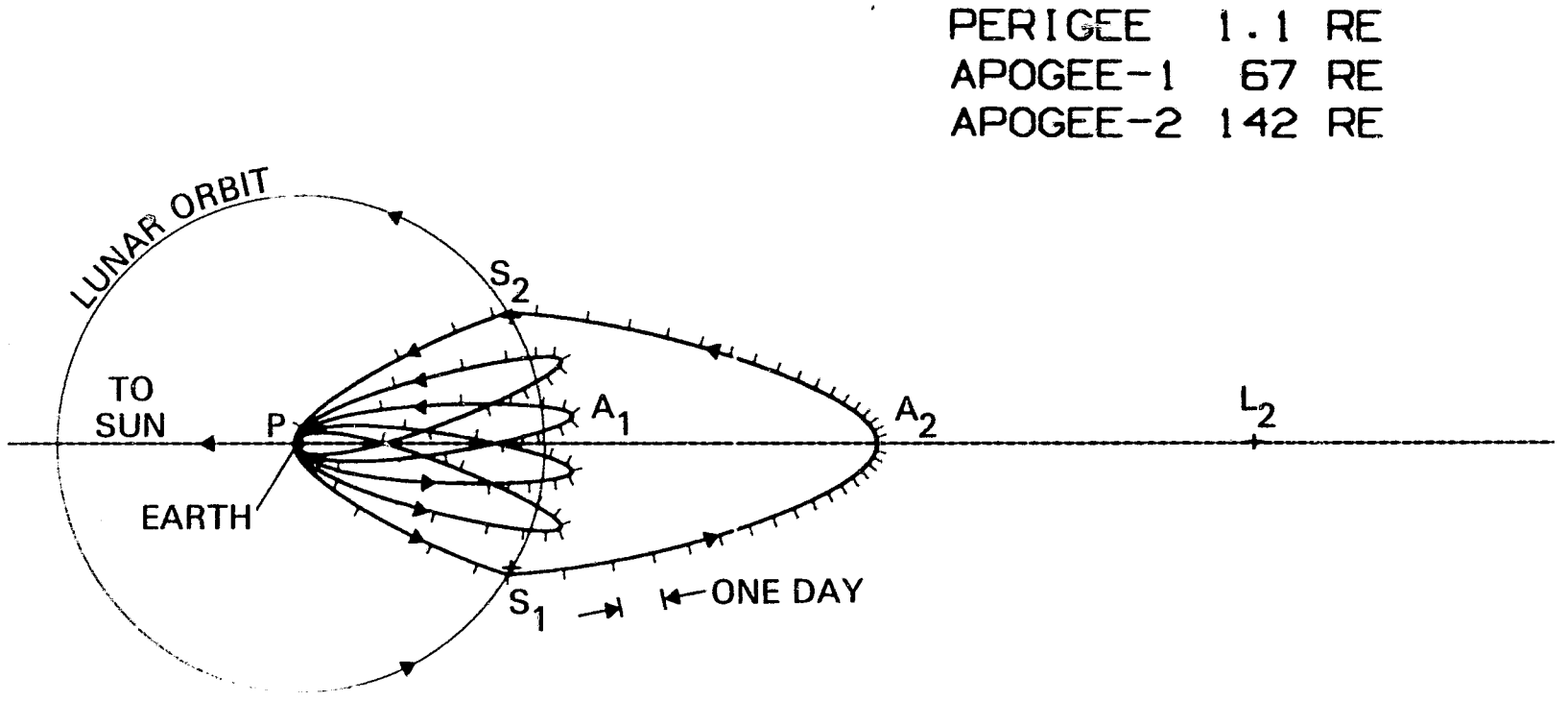


Figure 3-7. DOUBLE LUNAR SWINGBY ORBIT - [2,4,1] CLASS

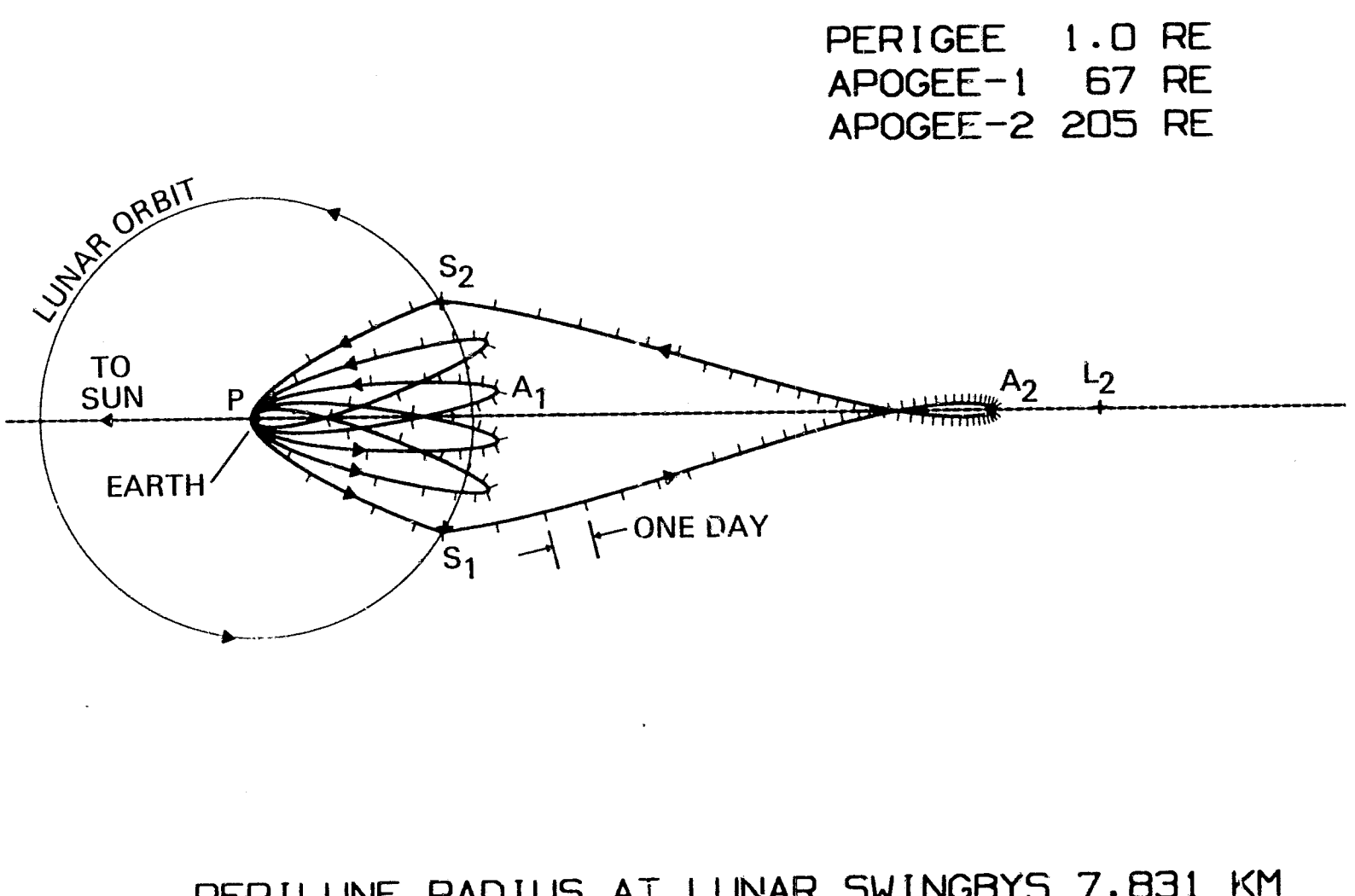


Figure 3-8. DOUBLE LUNAR SWINGBY ORBIT - [2,4,2] CLASS

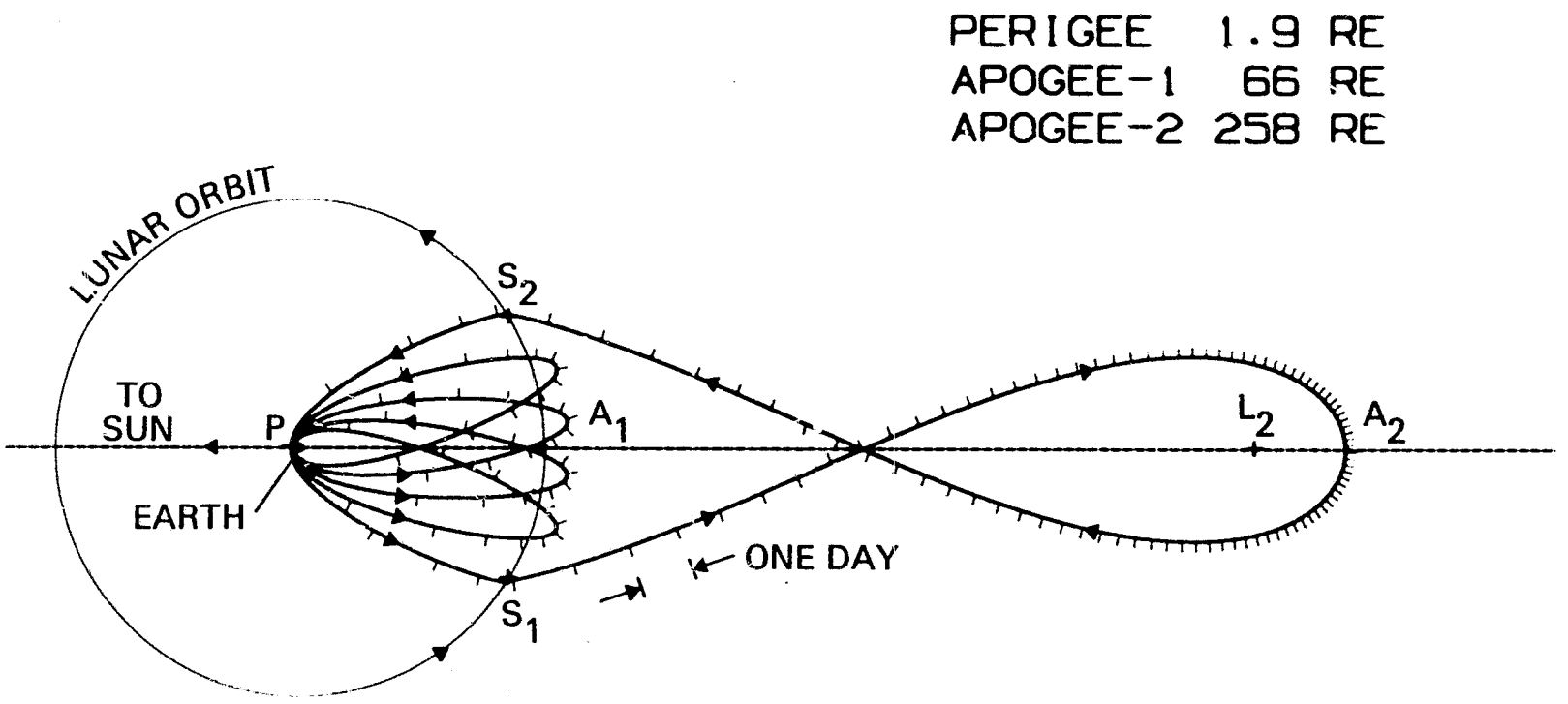


Figure 3-9. DOUBLE LUNAR SWINGBY ORBIT - [2,4,3] CLASS

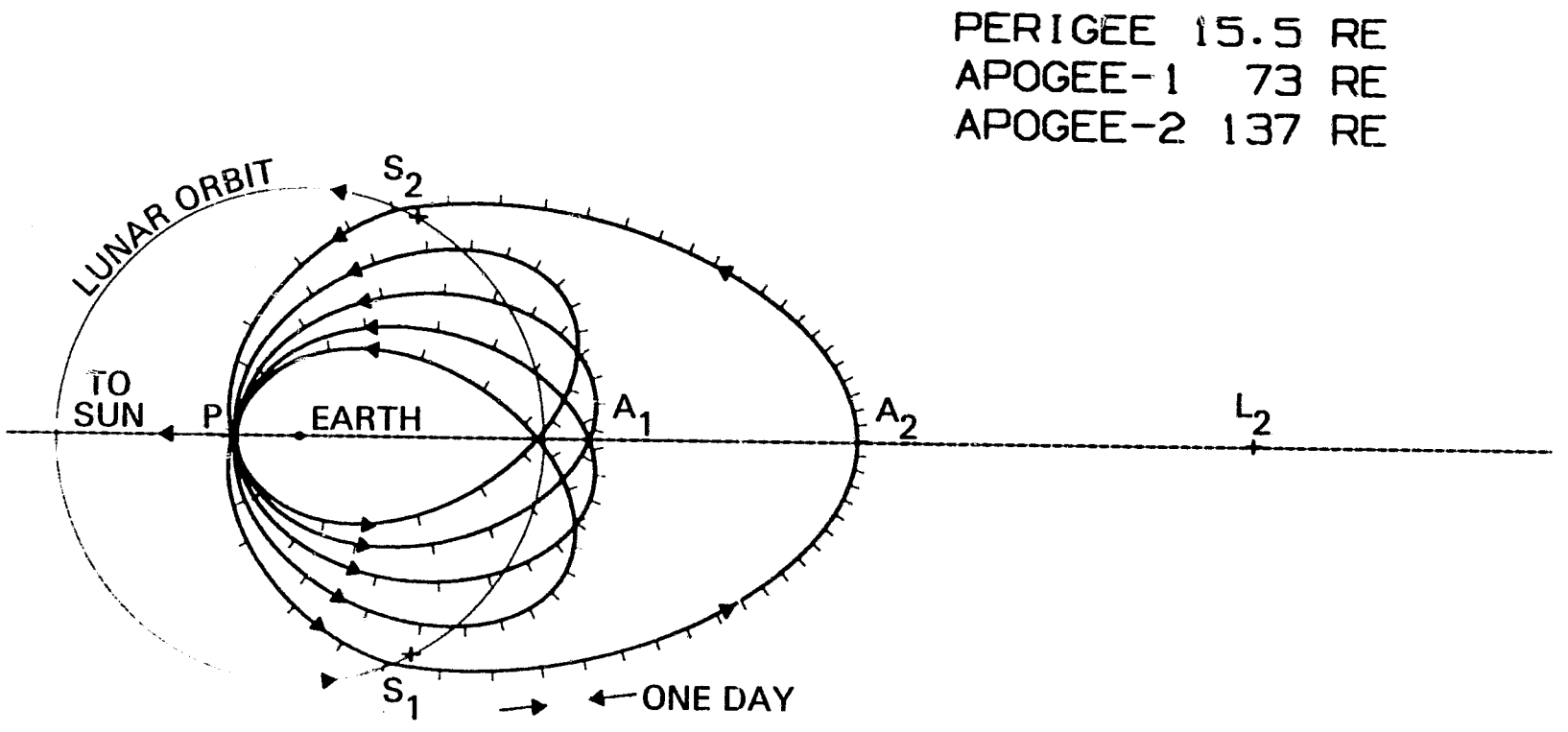


Figure 3-10. DOUBLE LUNAR SWINGBY ORBIT - [3,4,1] CLASS

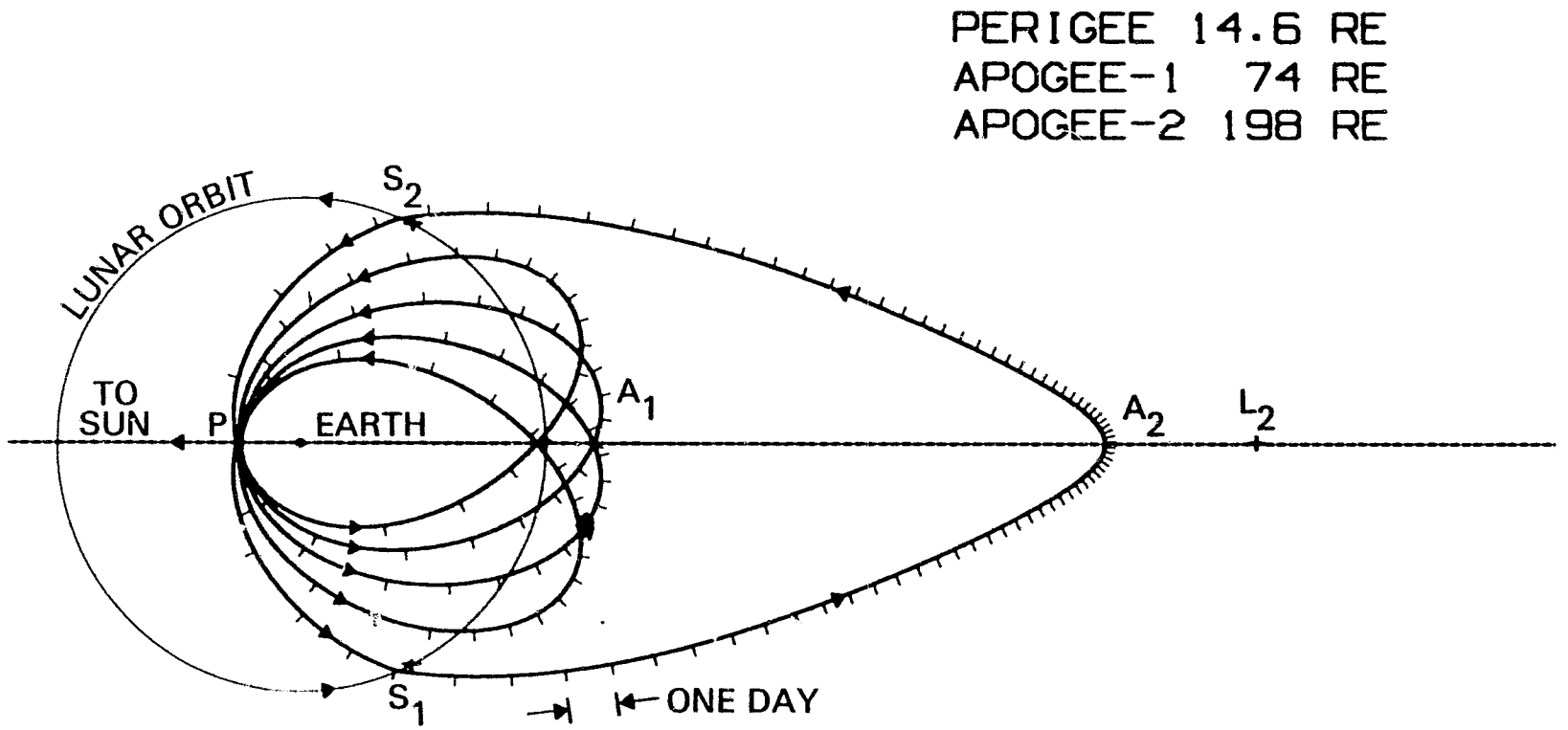


Figure 3-11. DOUBLE LUNAR SWINGBY ORBIT - [3,4,2] CLASS

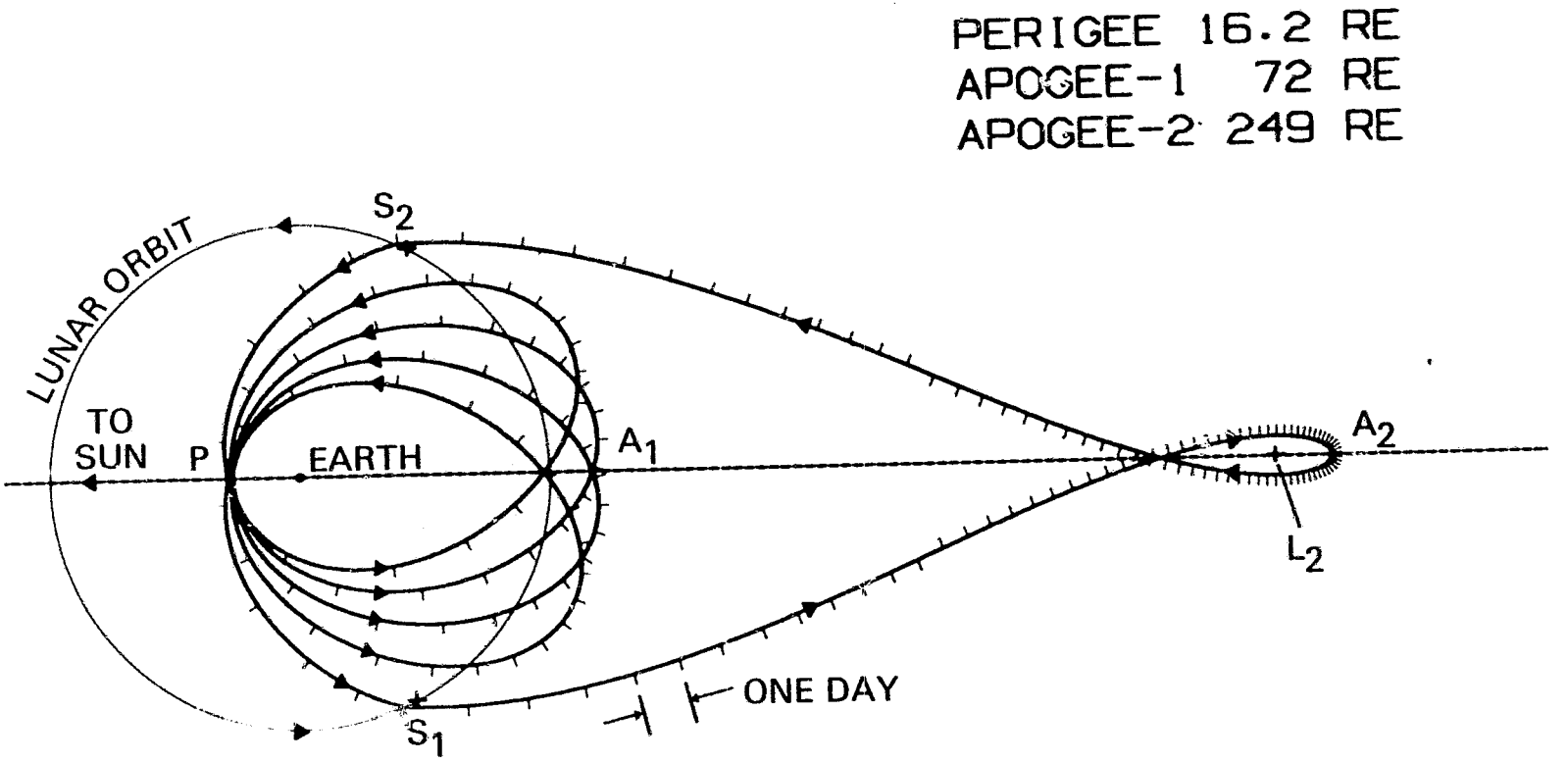


Figure 3-12. DOUBLE LUNAR SWINGBY ORBIT - [3,4,3] CLASS

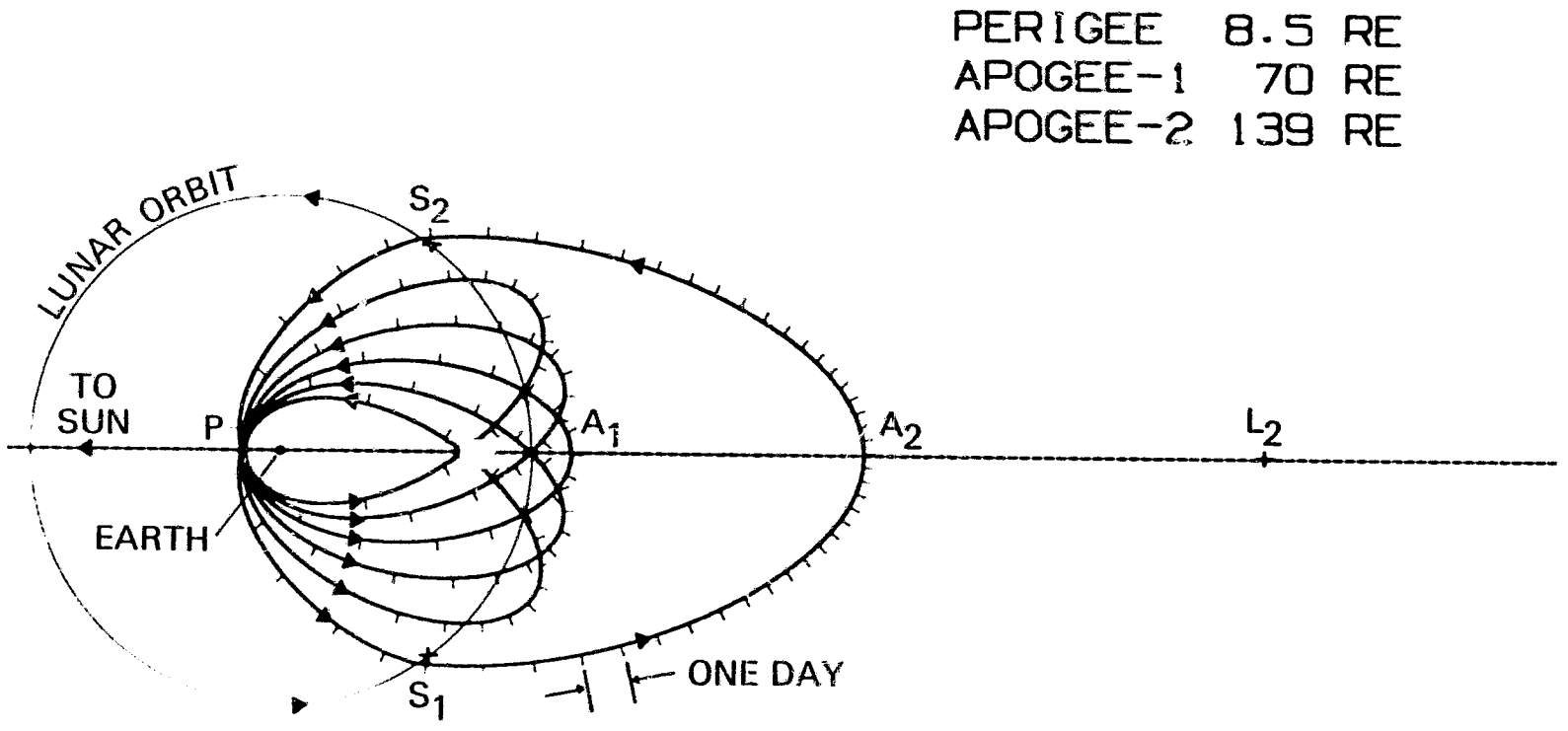


Figure 3-13. DOUBLE LUNAR SWINGBY ORBIT - [3,5,1] CLASS

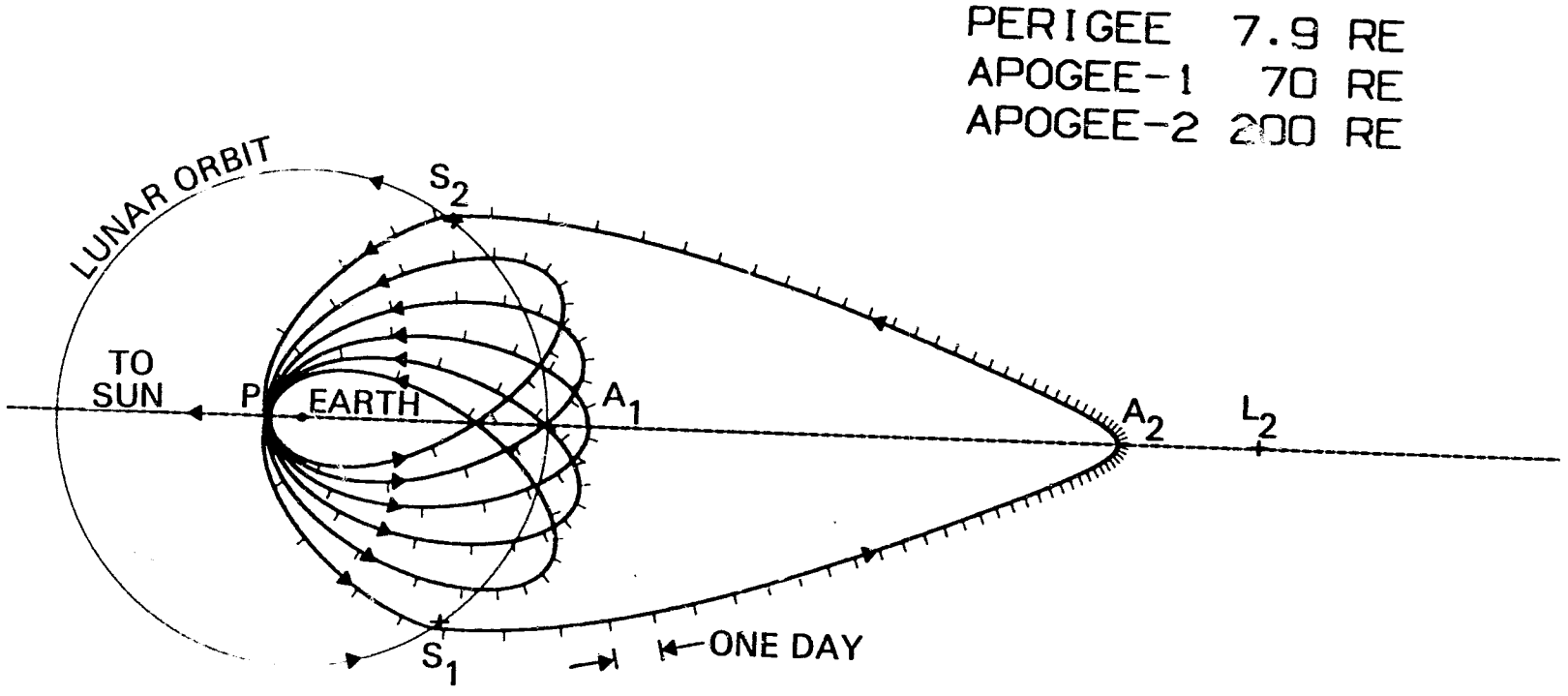


Figure 3-14. DOUBLE LUNAR SWINGBY ORBIT - [3,5,2] CLASS

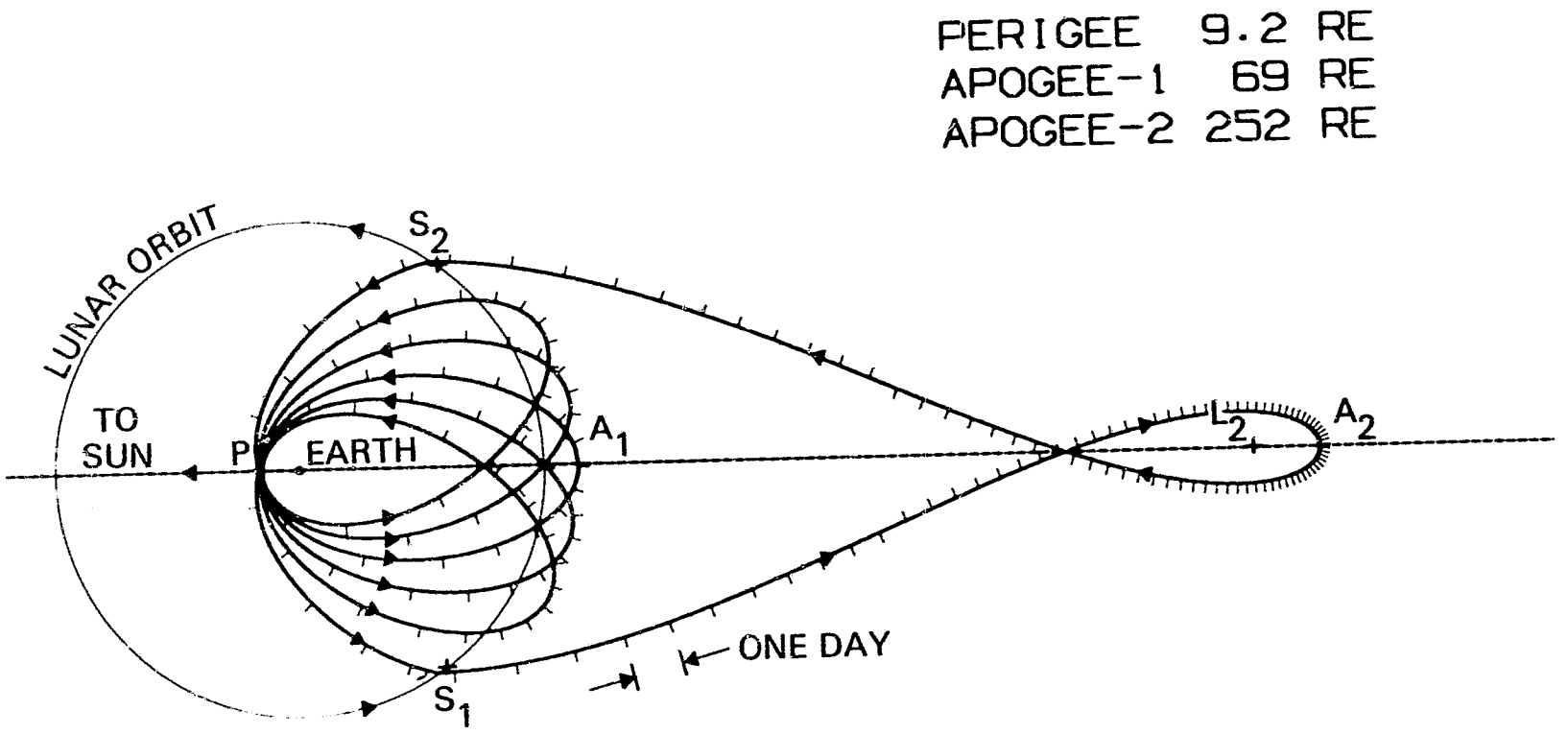


Figure 3-15. DOUBLE LUNAR SWINGBY ORBIT - [3,5,3] CLASS

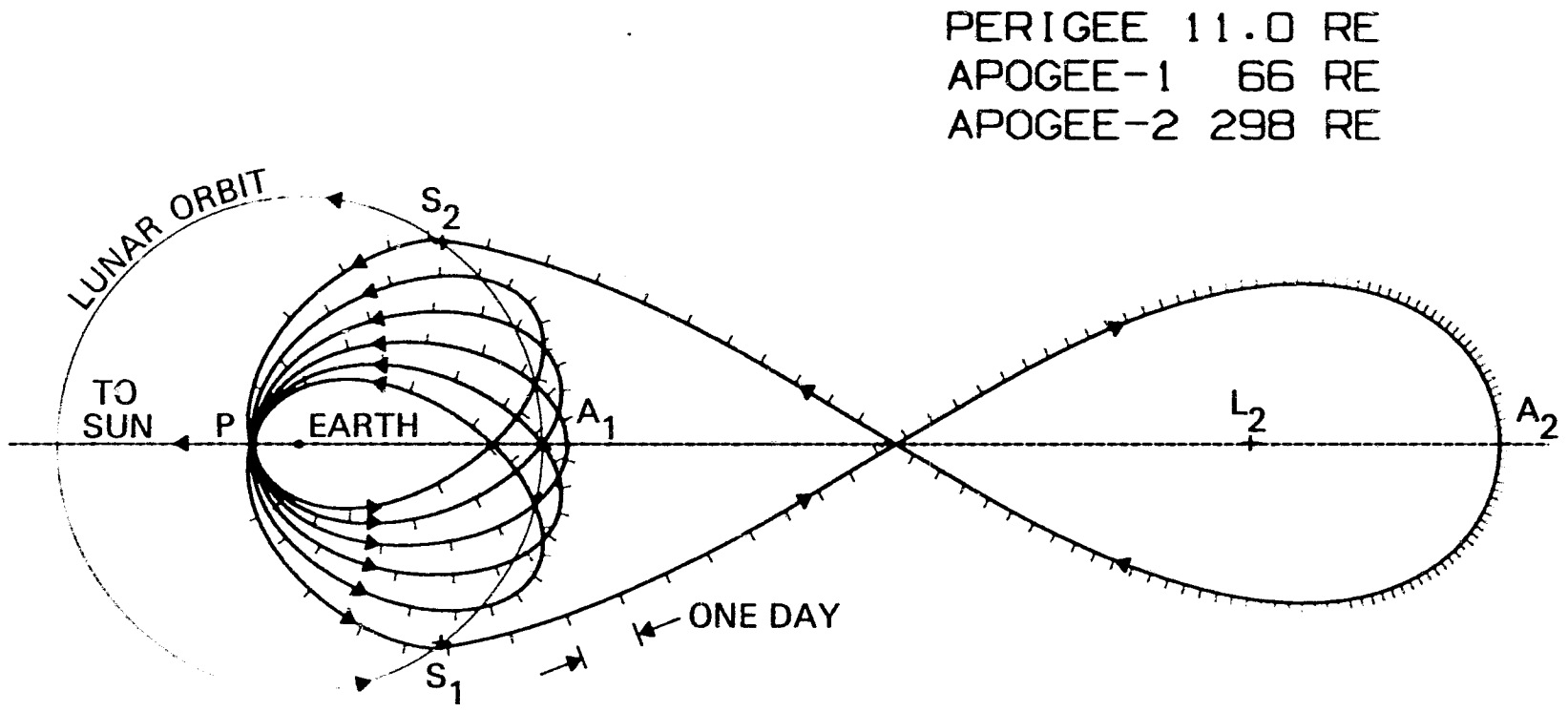


Figure 3-16. DOUBLE LUNAR SWINGBY ORBIT - [3,5,4] CLASS

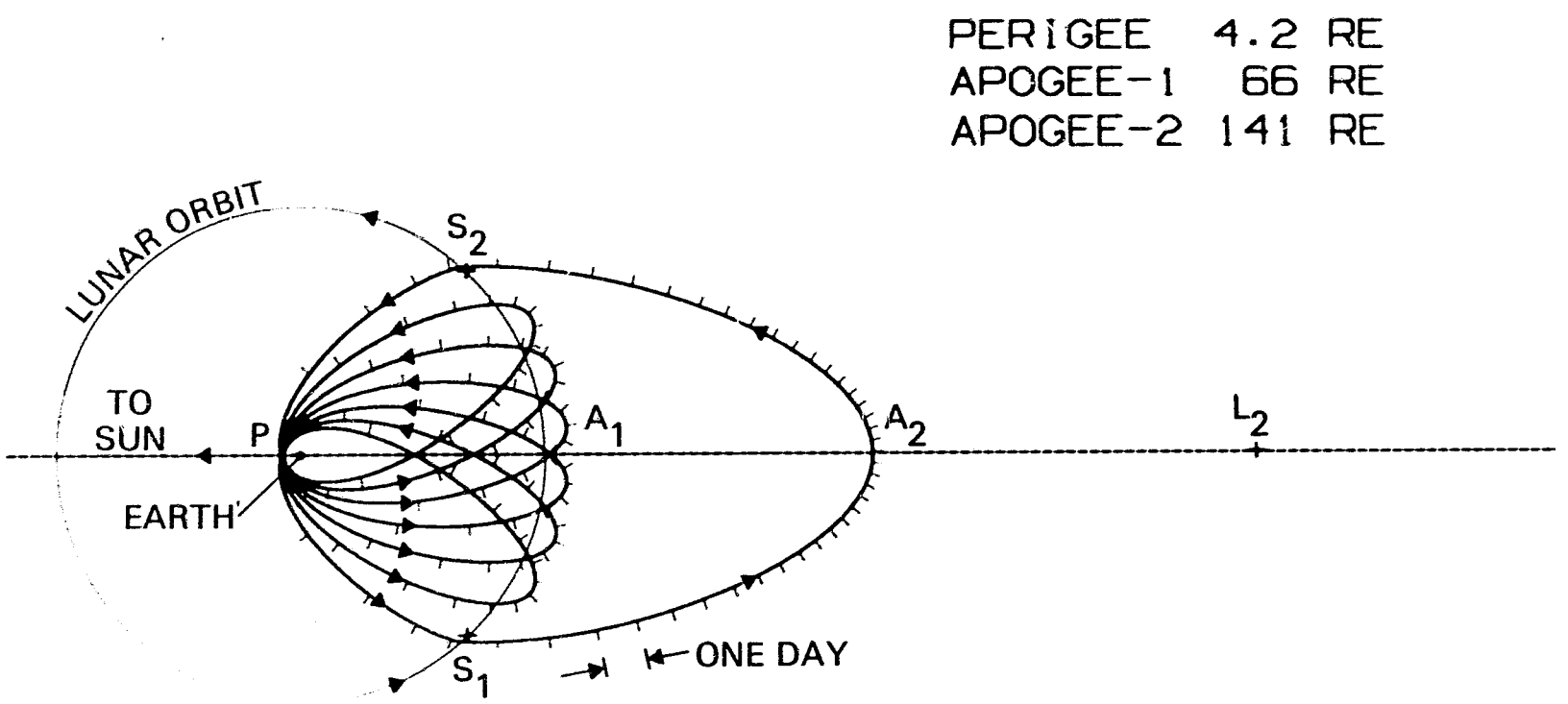


Figure 3-17. DOUBLE LUNAR SWINGBY ORBIT - [3,6,1] CLASS

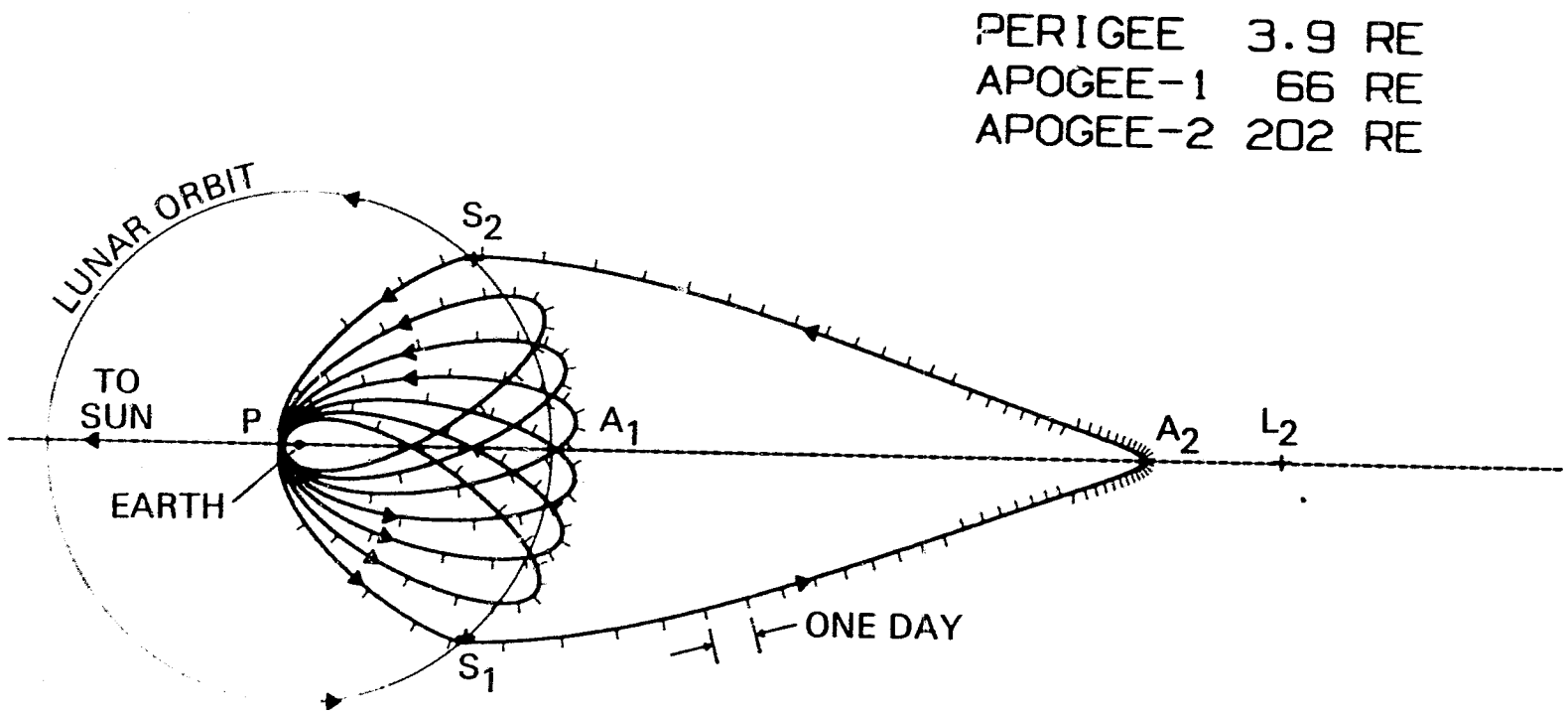


Figure 3-18. DOUBLE LUNAR SWINGBY ORBIT -- [3,6,2] CLASS

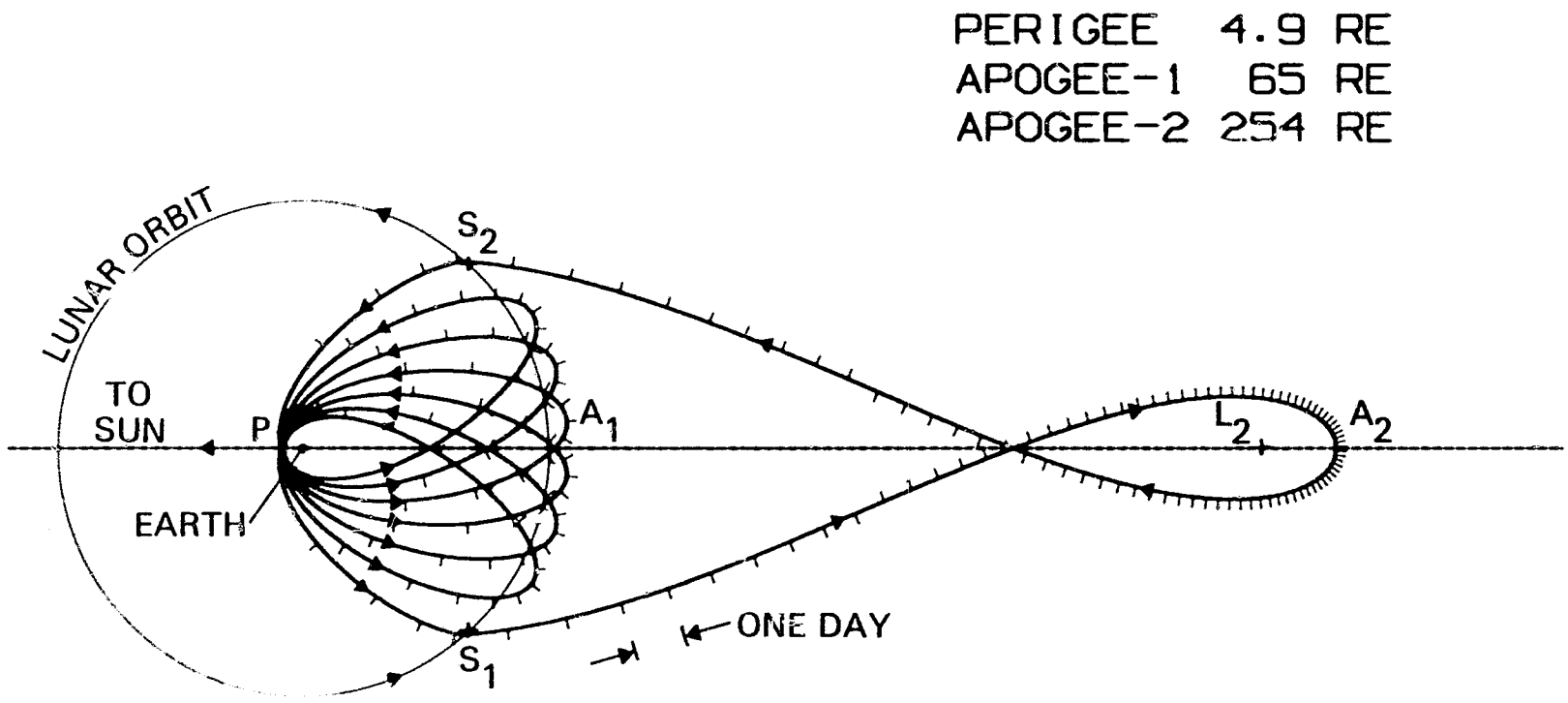


Figure 3-19. DOUBLE LUNAR SWINGBY ORBIT - [3,6,3] CLASS

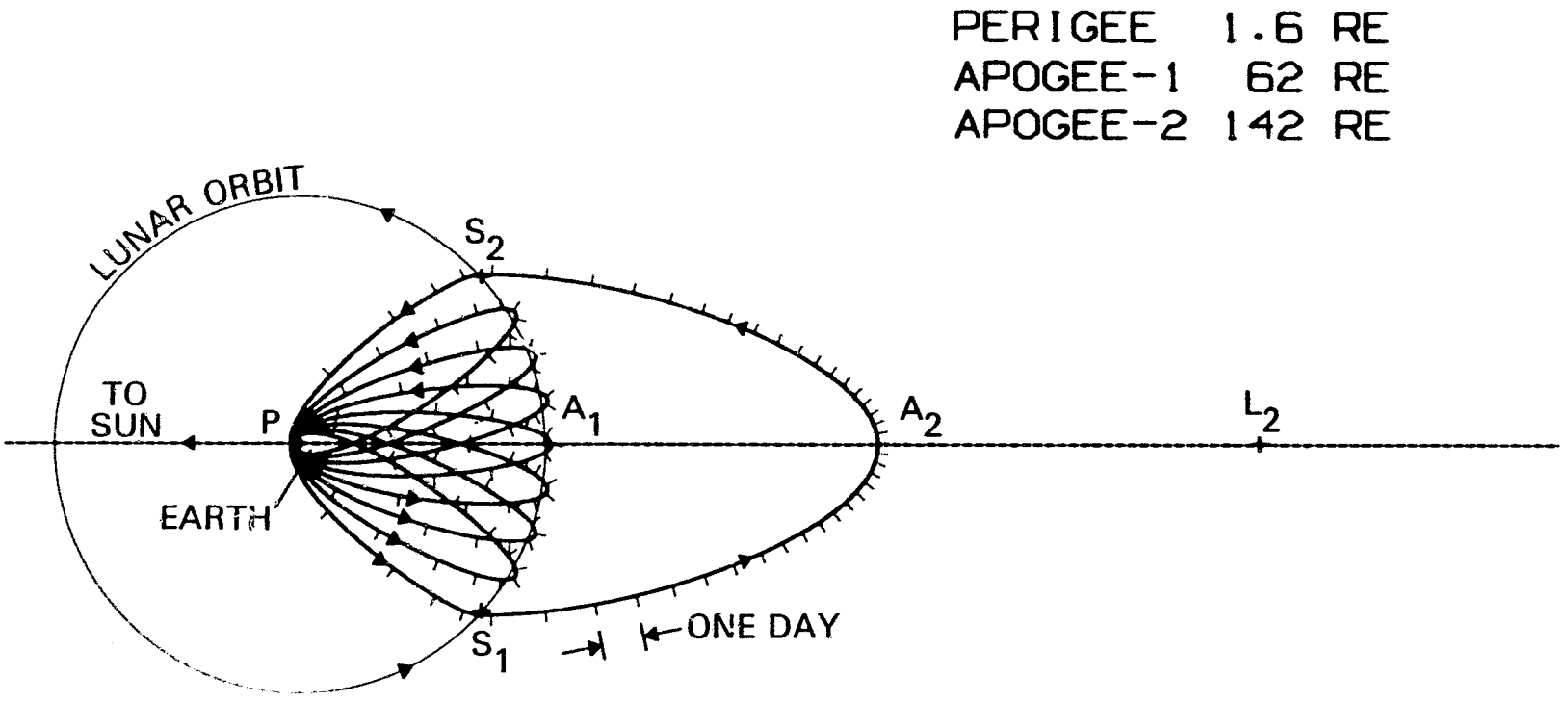


Figure 3-20. DOUBLE LUNAR SWINGBY ORBIT - [3,7,1] CLASS

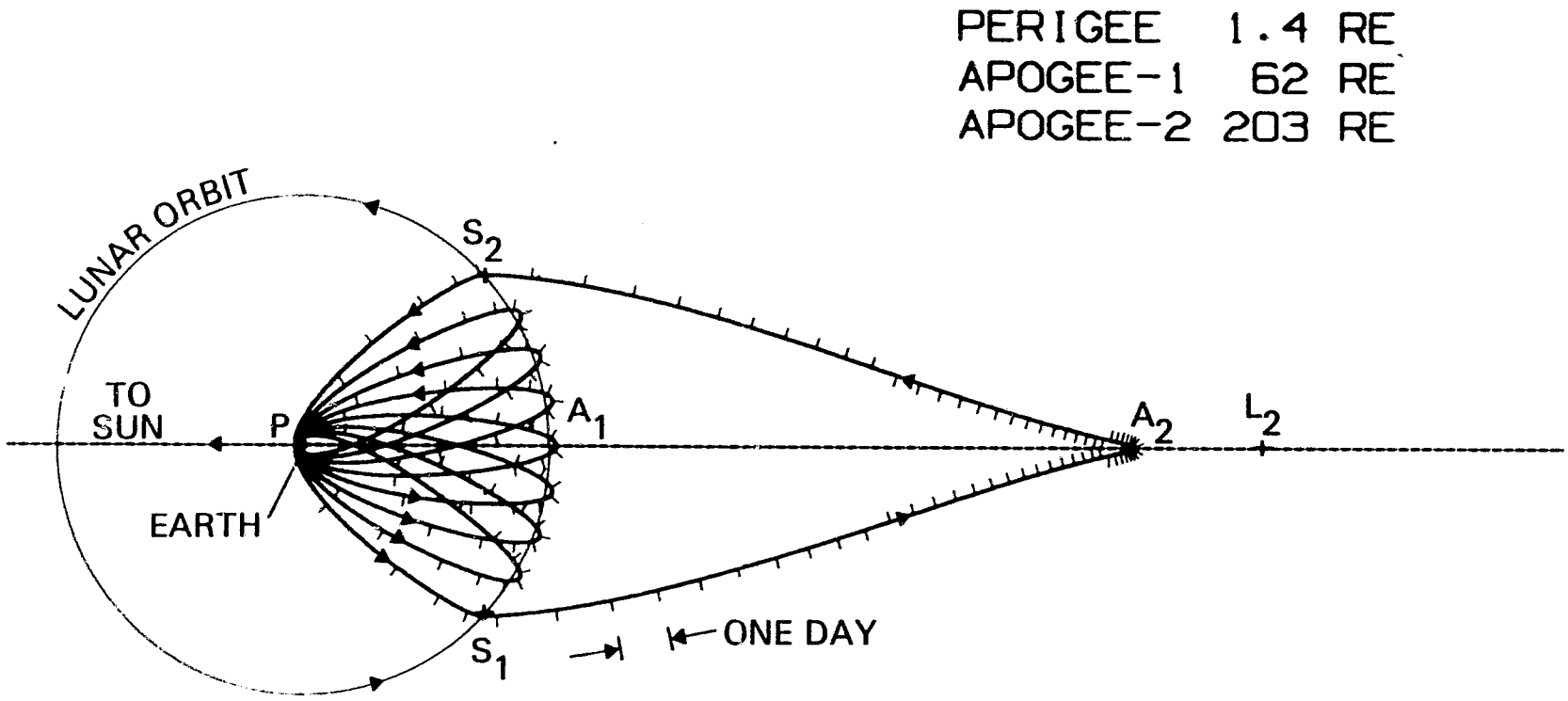
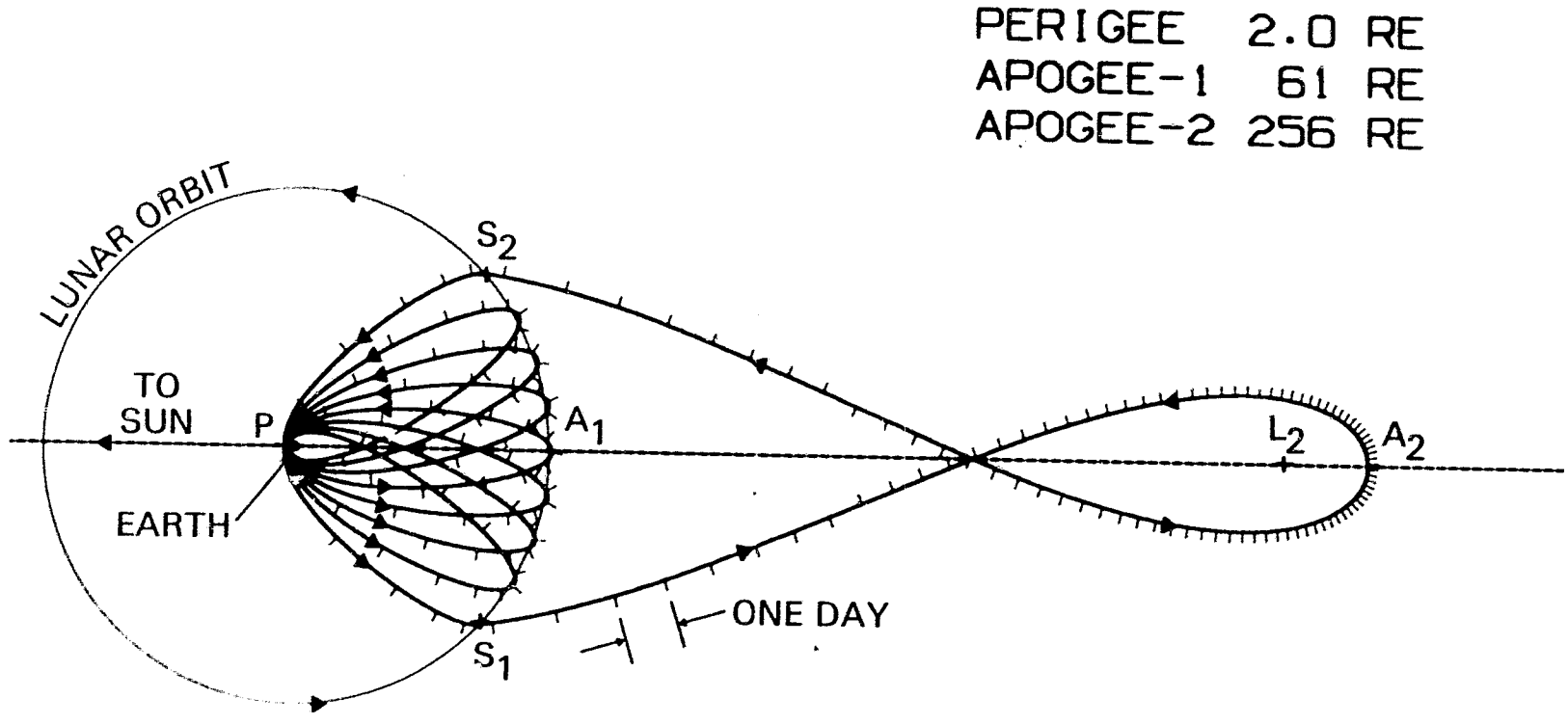


Figure 3-21. DOUBLE LUNAR SWINGBY ORBIT - [3,7,2] CLASS



PERILUNE RADIUS AT LUNAR SWINGBYS 4.795 KM

Figure 3-22. DOUBLE LUNAR SWINGBY ORBIT - [3,7,3] CLASS

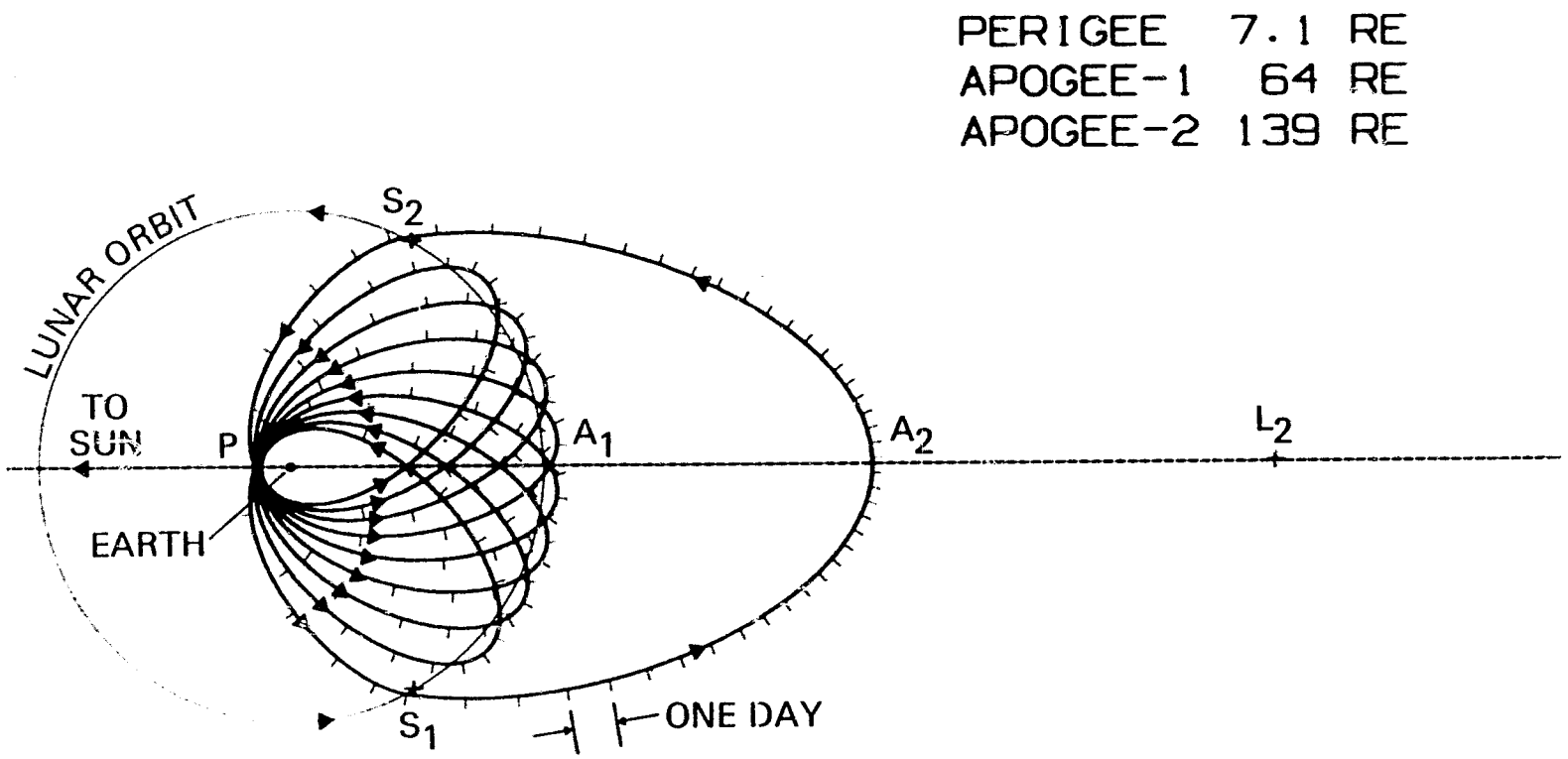


Figure 3-23. DOUBLE LUNAR SWINGBY ORBIT-[4,8,1] CLASS

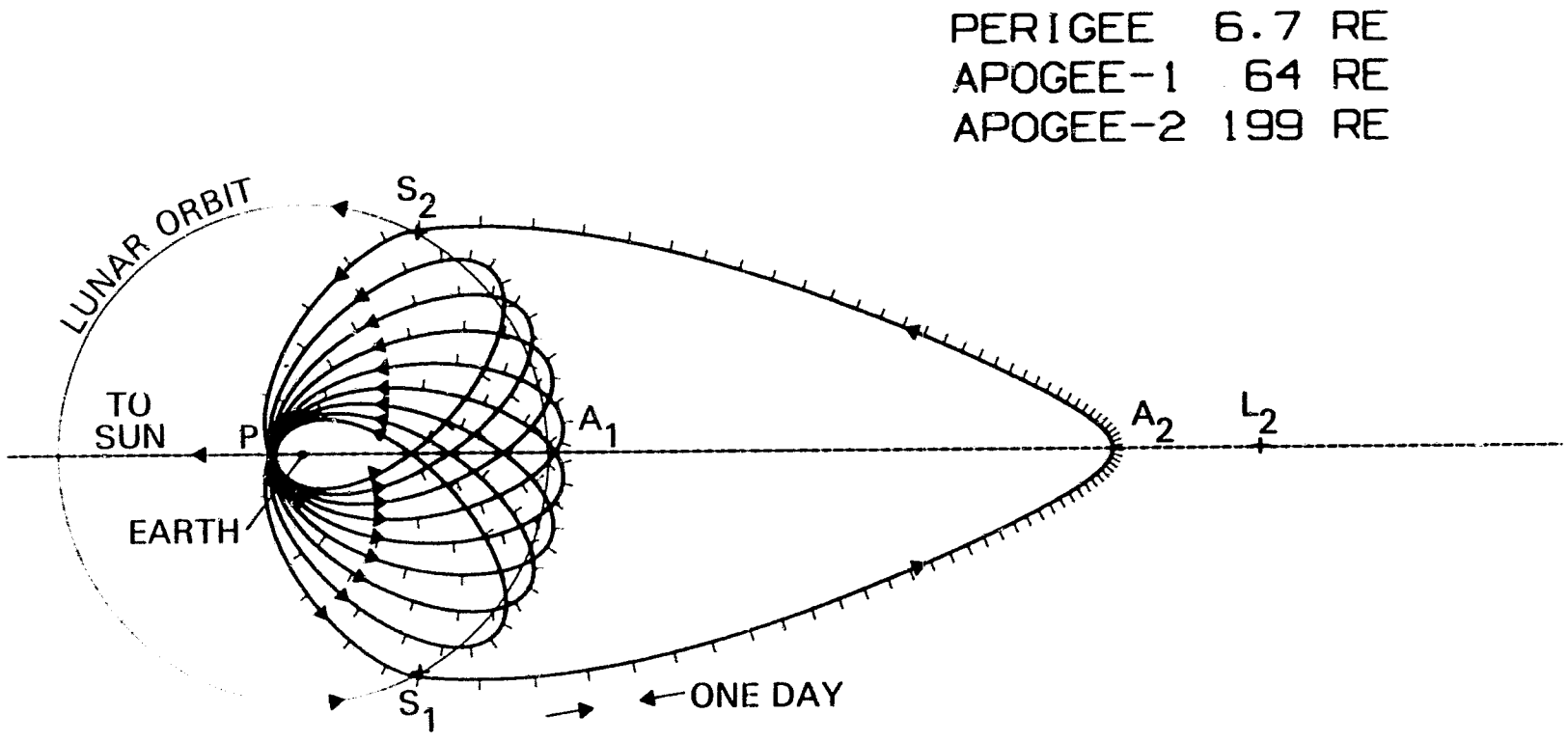
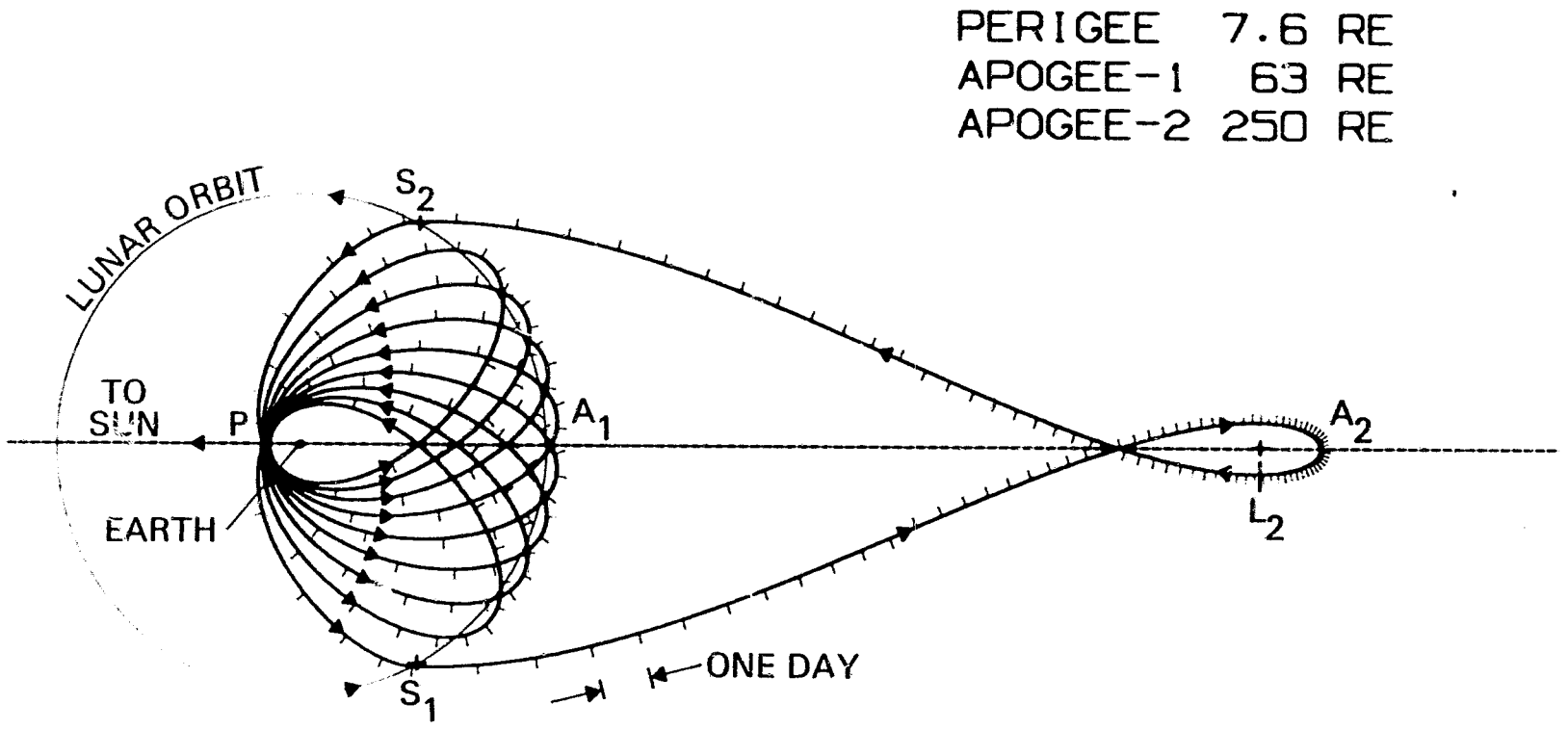


Figure 3-24. DOUBLE LUNAR SWINGBY ORBIT - [4,8,2] CLASS



PERILUNE RADIUS AT LUNAR SWINGBYS 8,821 KM

Figure 3-25. DOUBLE LUNAR SWINGBY ORBIT - [4,8,3] CLASS

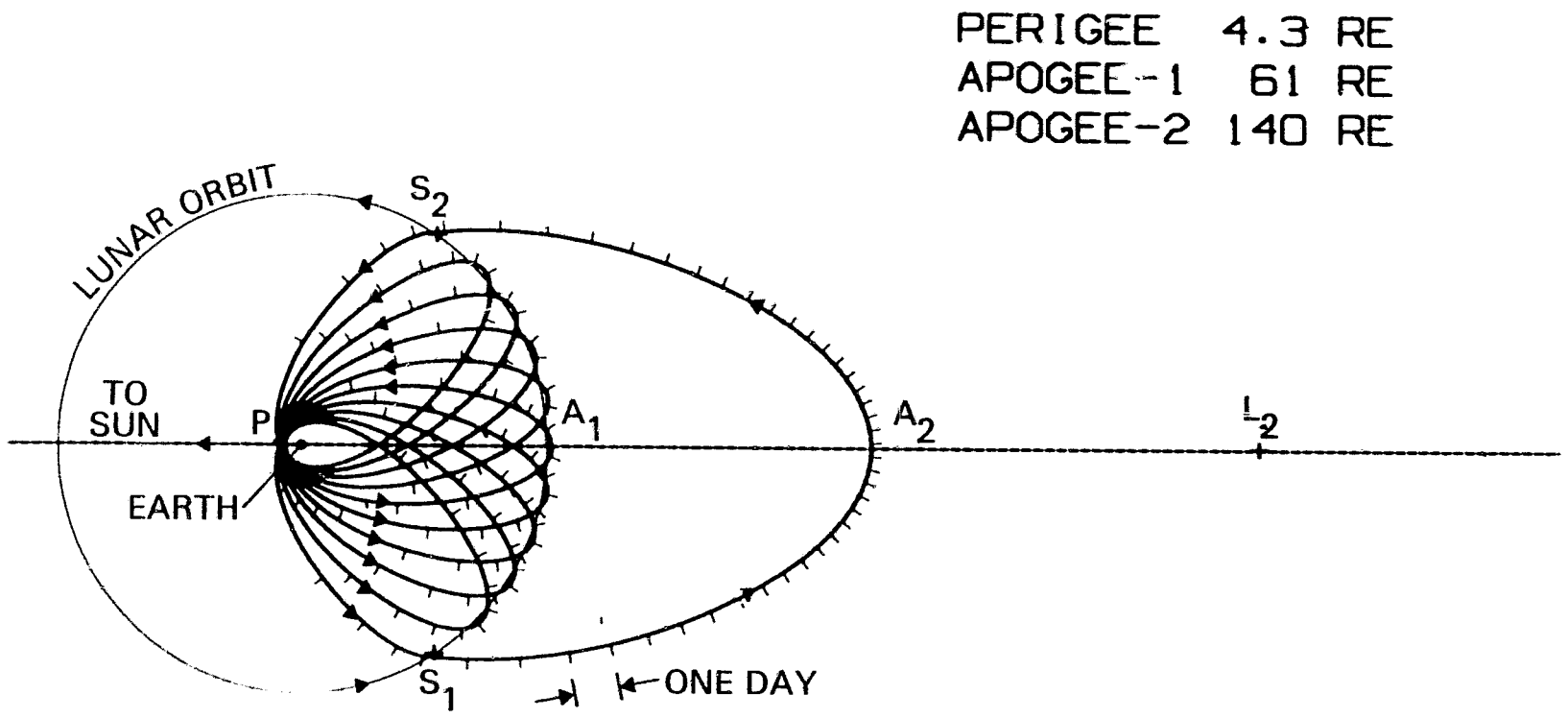


Figure 3-26. DOUBLE LUNAR SWINGBY ORBIT - [4,9,1] CLASS

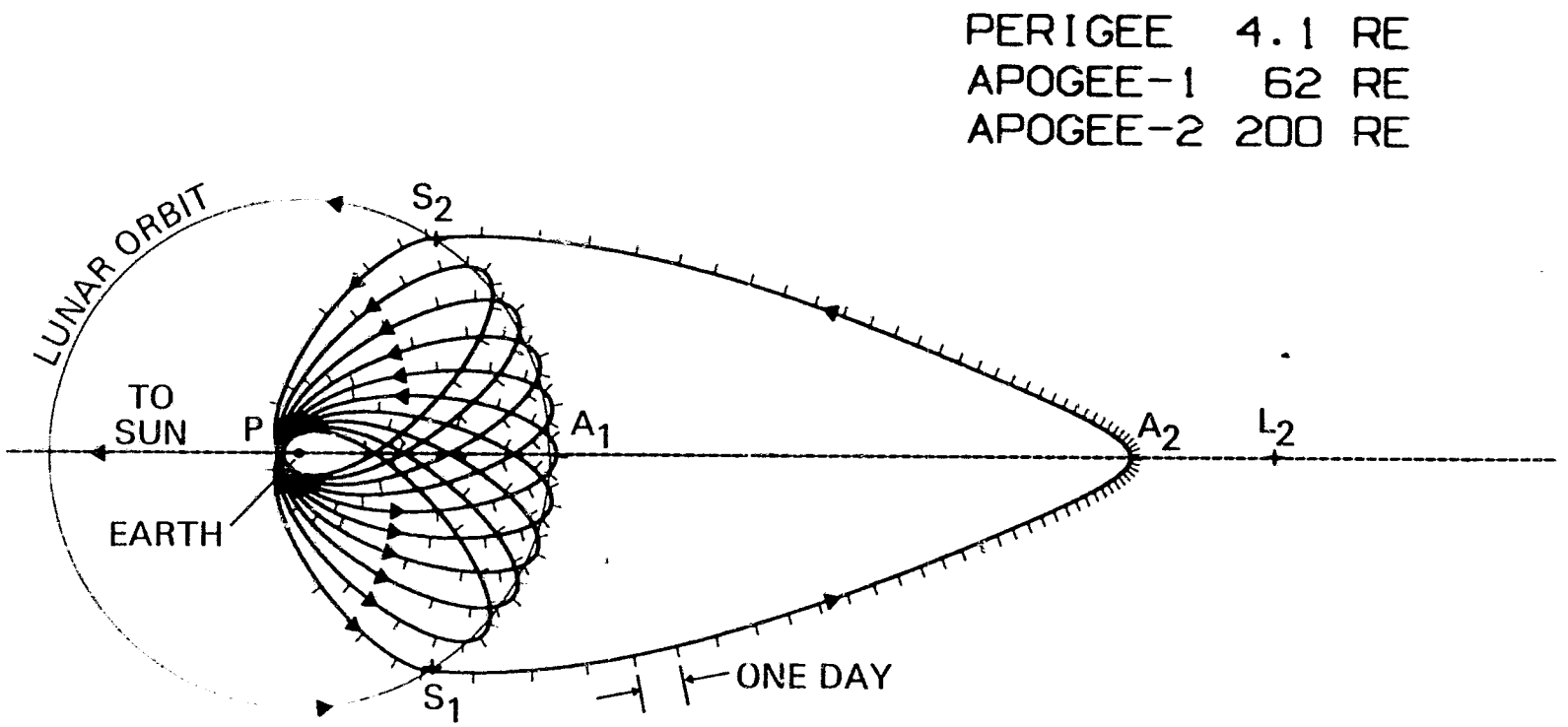


Figure 3-27. DOUBLE LUNAR SWINGBY ORBIT - [4,9,2] CLASS

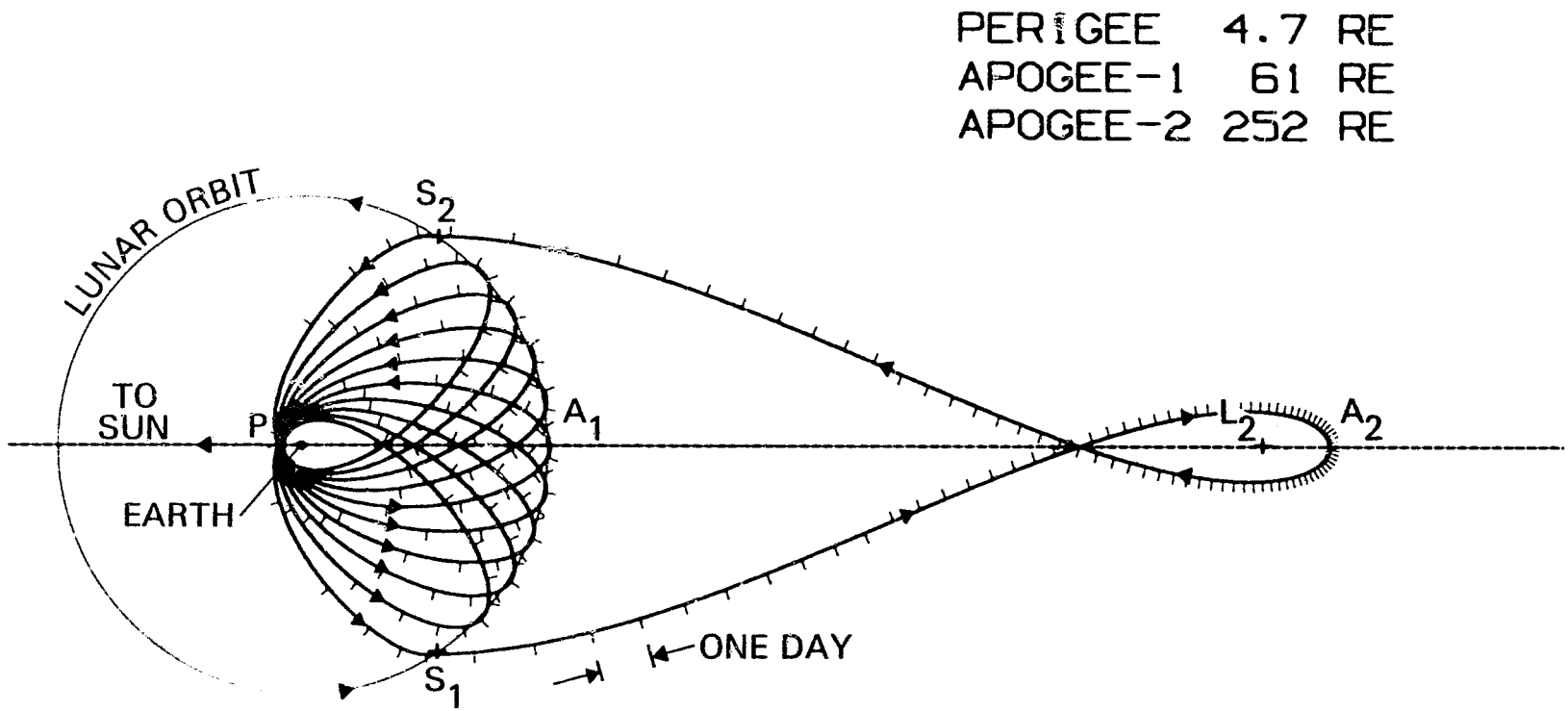


Figure 3-28. DOUBLE LUNAR SWINGBY ORBIT - [4,9,3] CLASS

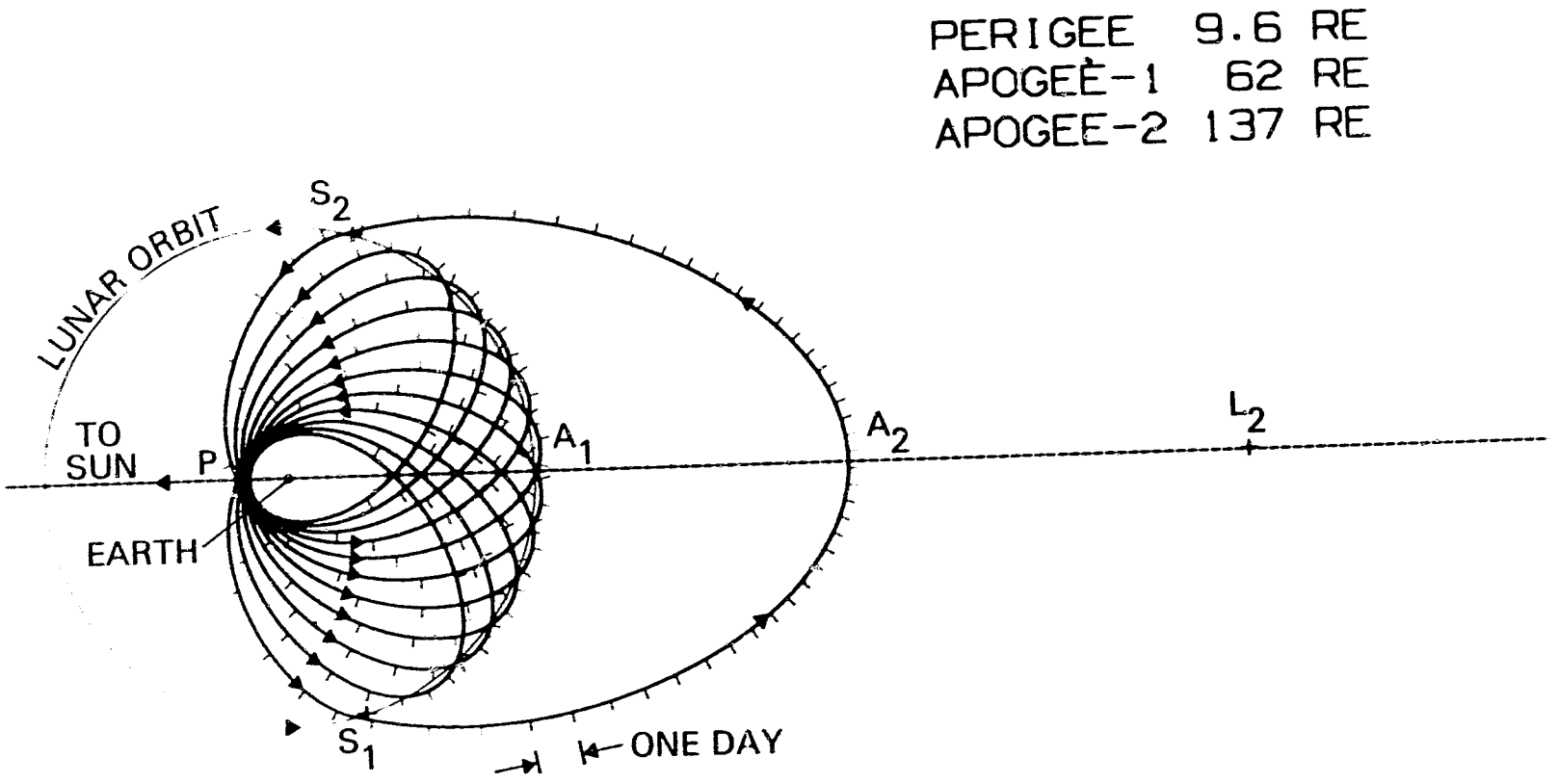


Figure 3-29. DOUBLE LUNAR SWINGBY ORBIT - [5,10,1] CLASS

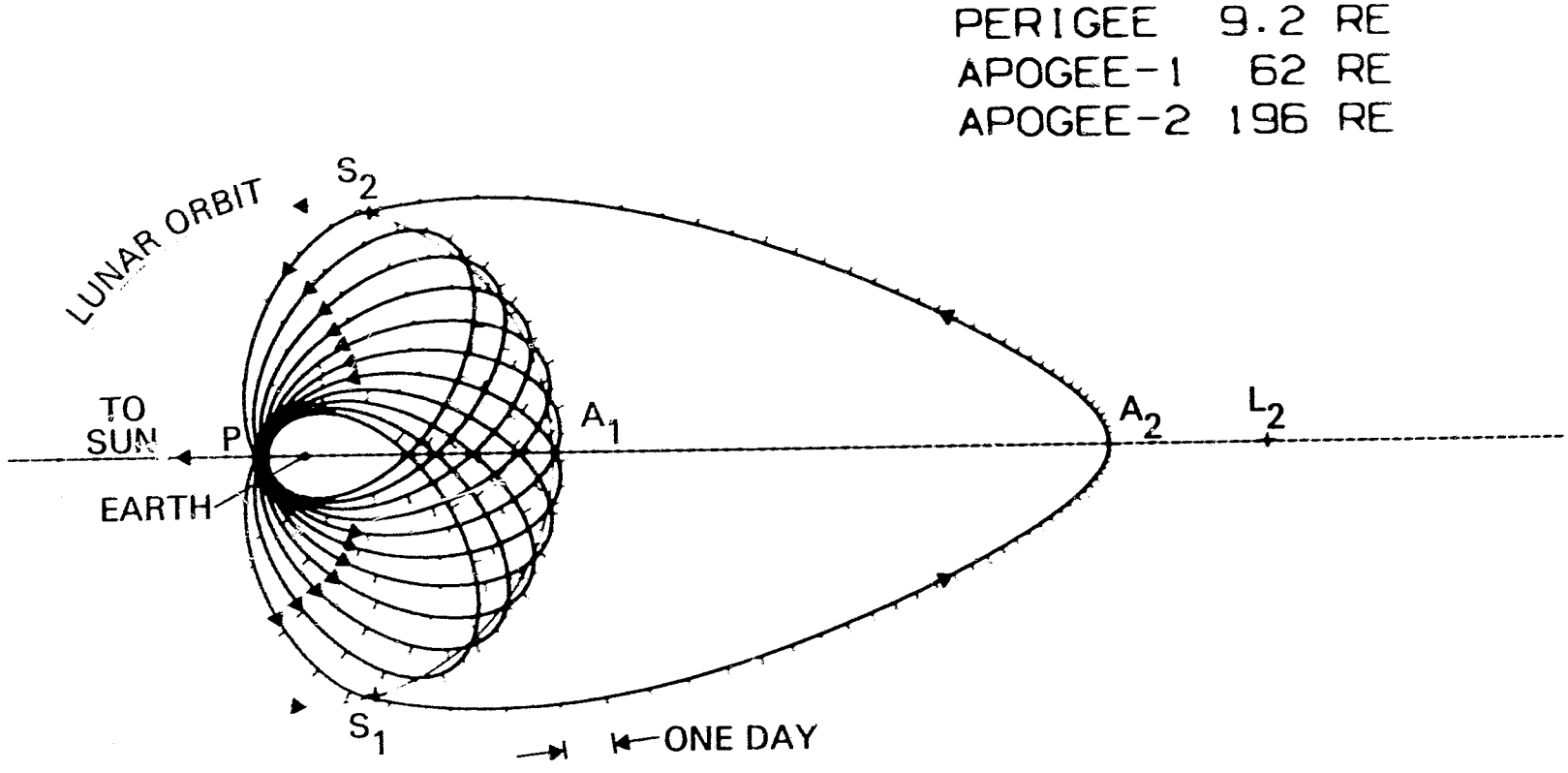


Figure 3-30. DOUBLE LUNAR SWINGBY ORBIT - [5,10,2] CLASS

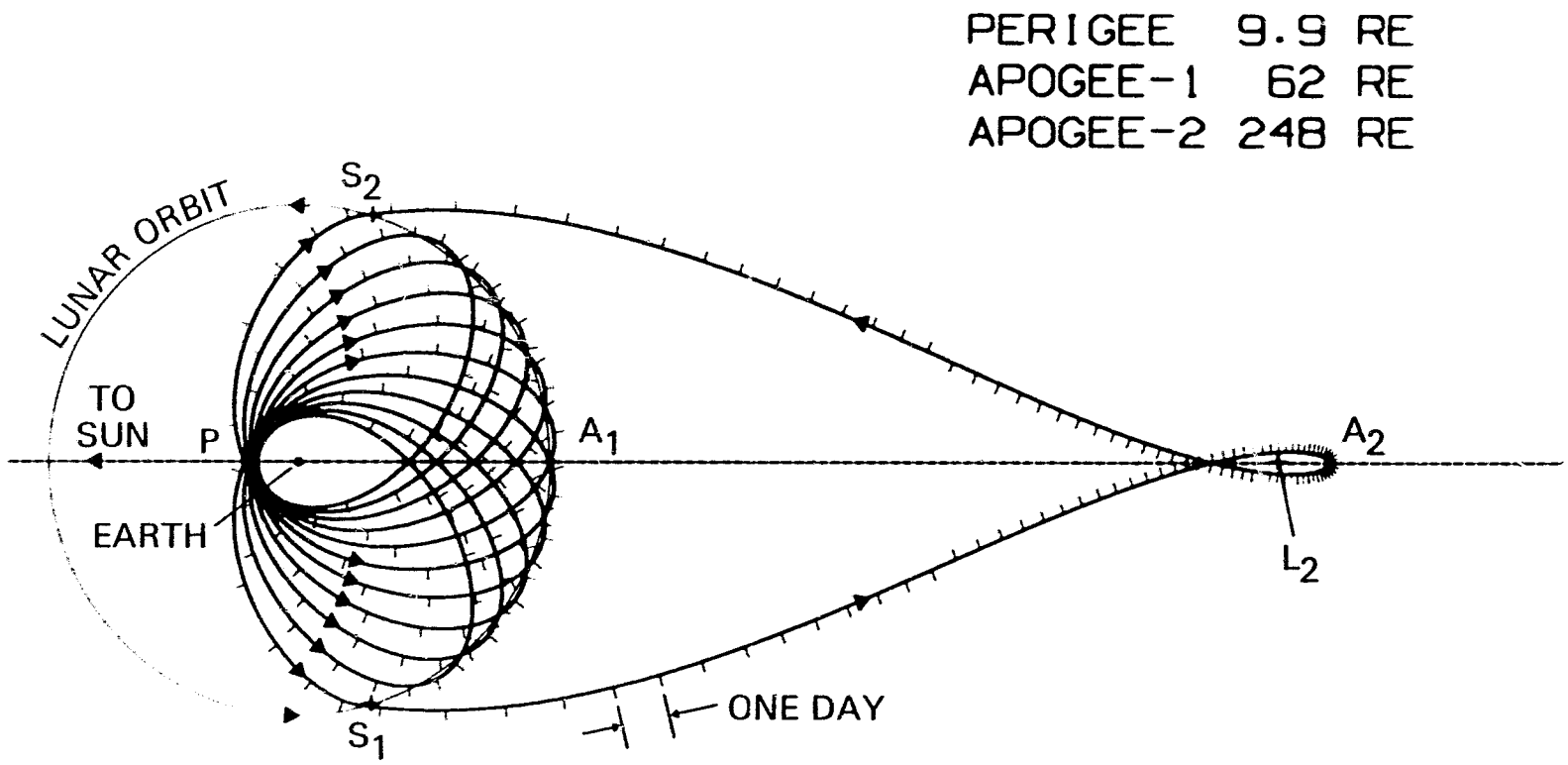


Figure 3-31. DOUBLE LUNAR SWINGBY ORBIT - [5,10,3] CLASS

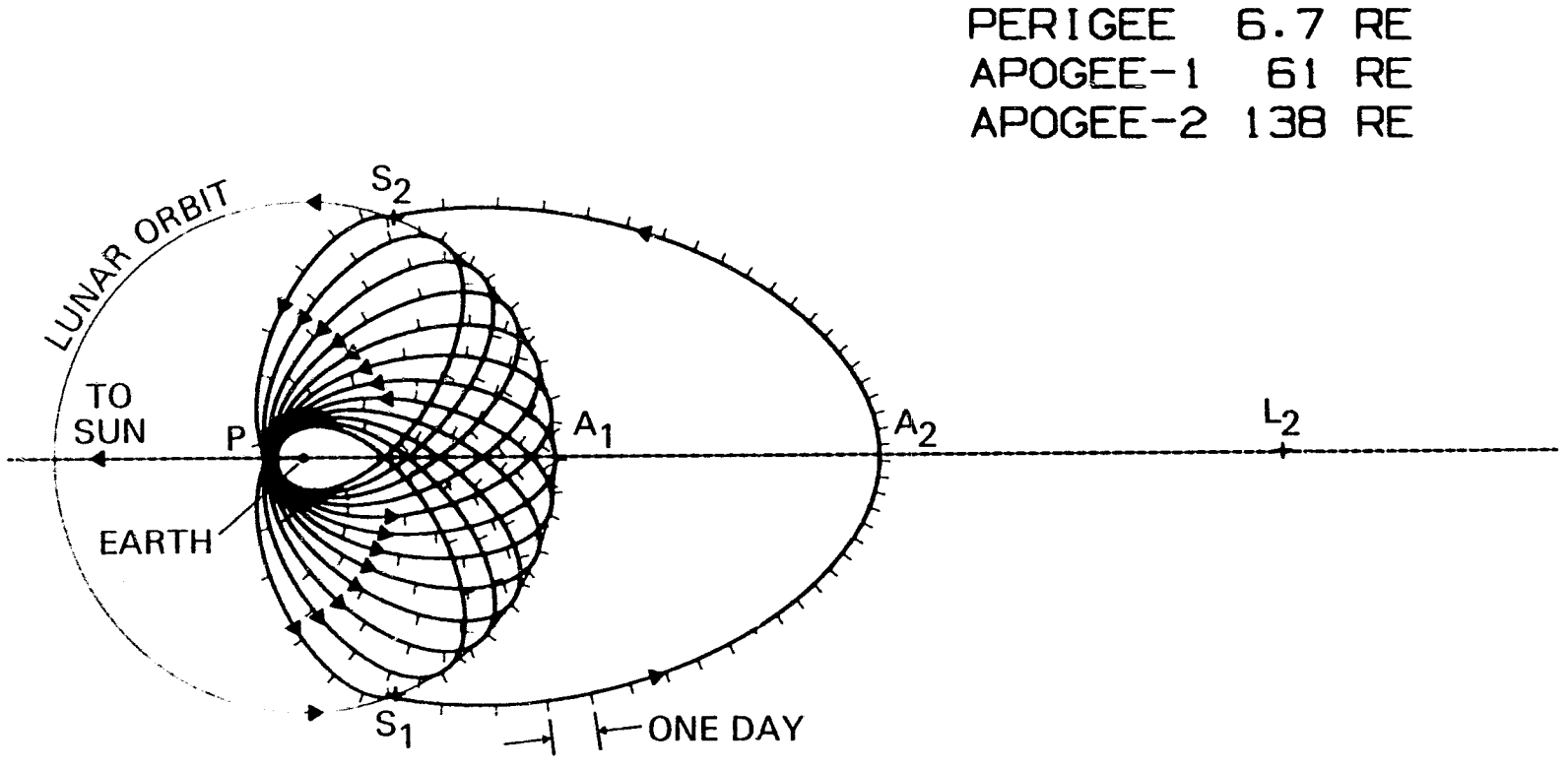


Figure 3-32. DOUBLE LUNAR SWINGBY ORBIT - [5,11,1] CLASS

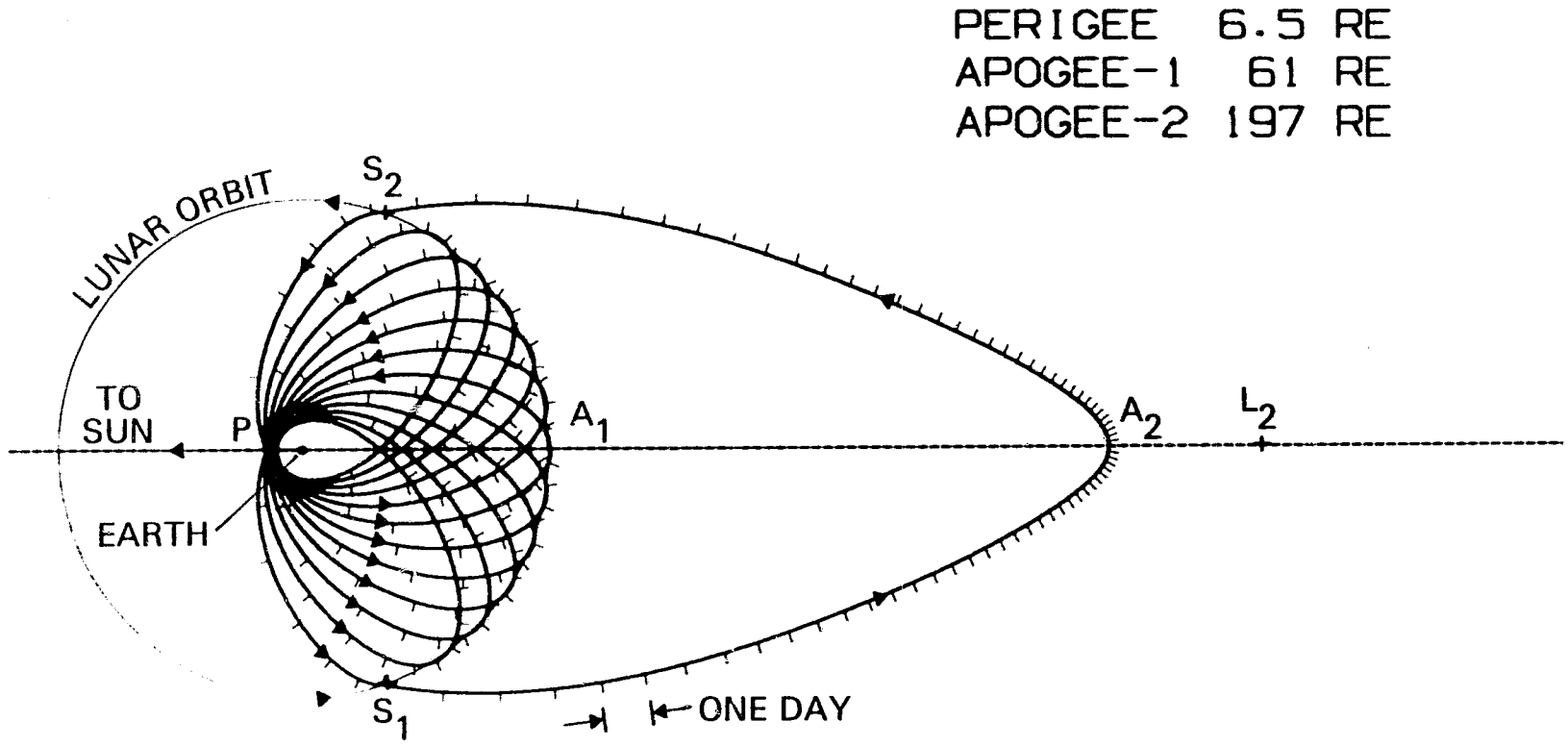


Figure 3-33. DOUBLE LUNAR SWINGBY ORBIT - [5,11,2] CLASS

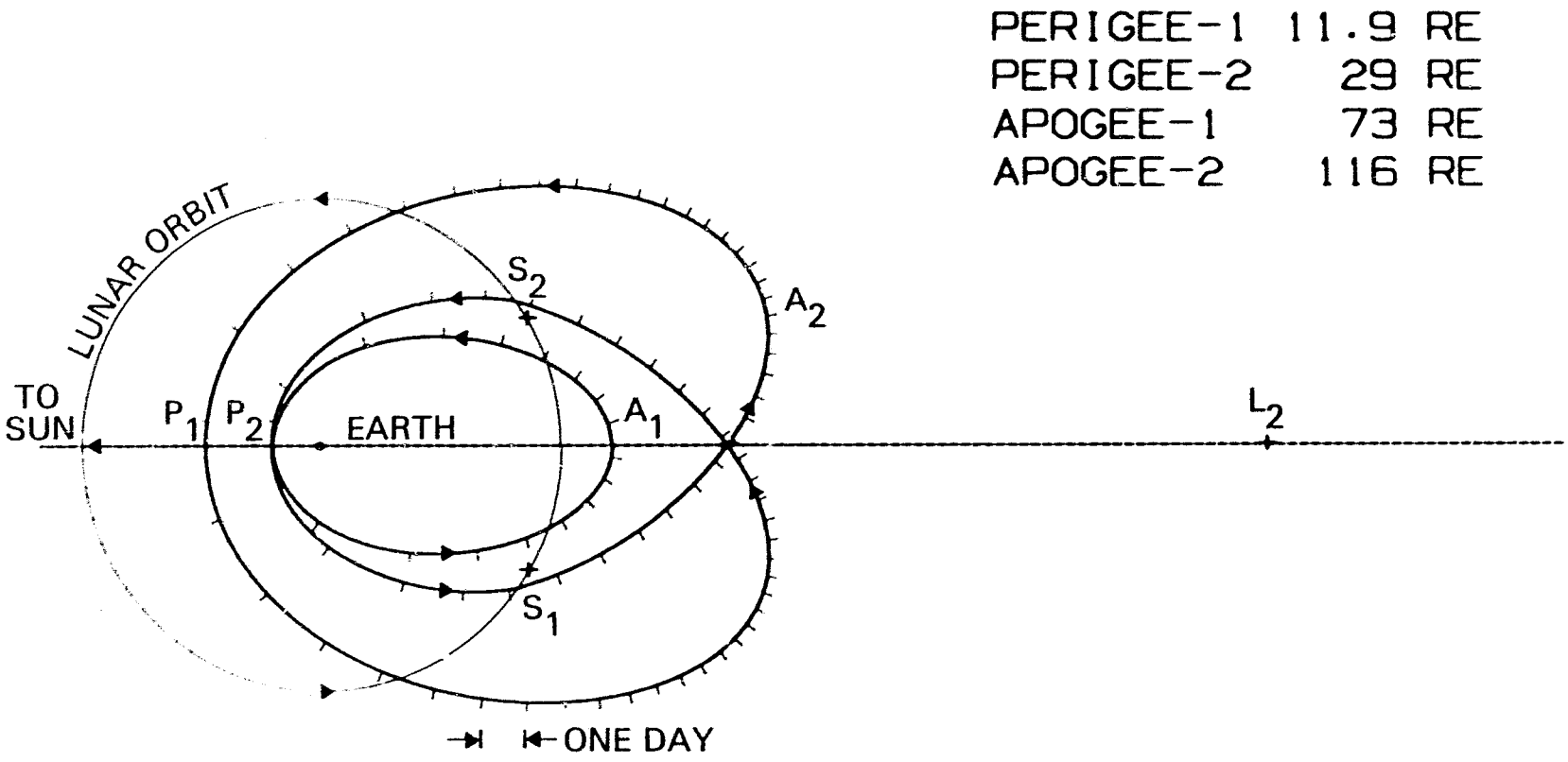


Figure 3-34. DOUBLE LUNAR SWINGBY ORBIT - [1,1,2,1] CLASS

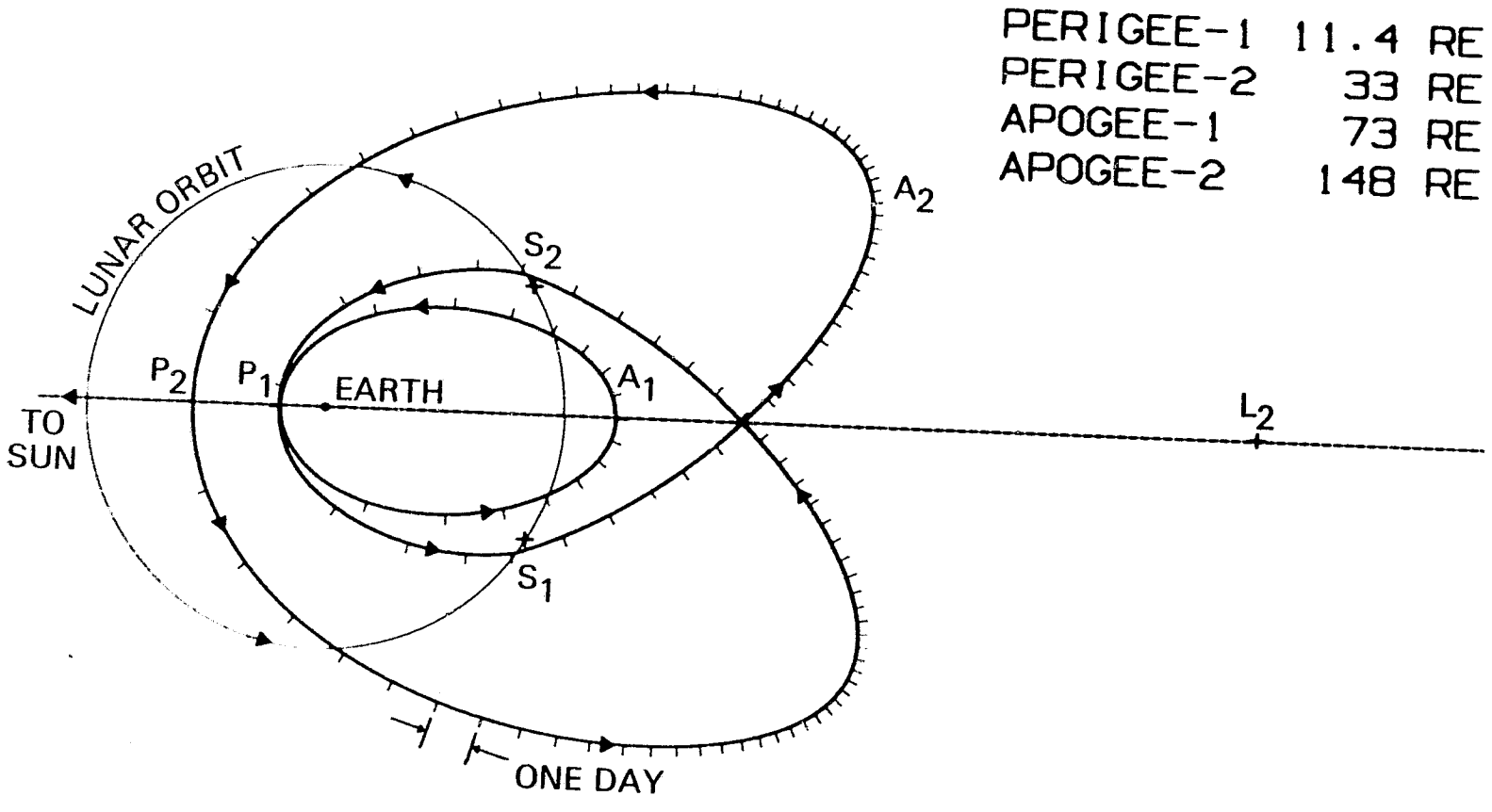


Figure 3-35. DOUBLE LUNAR SWINGBY ORBIT - [1,1,3,1] CLASS

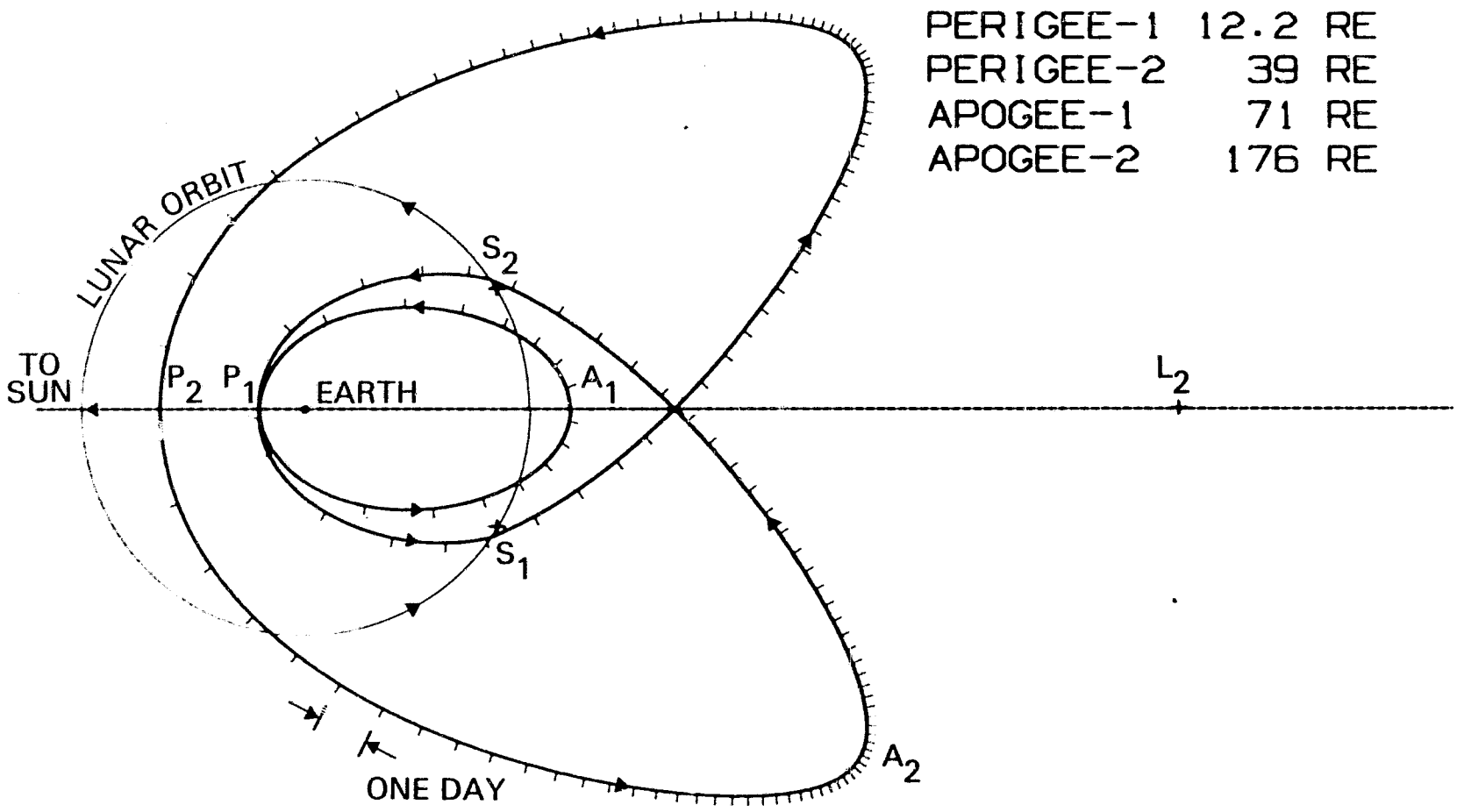


Figure 3-36. DOUBLE LUNAR SWINGBY ORBIT - [1,1,4,1] CLASS

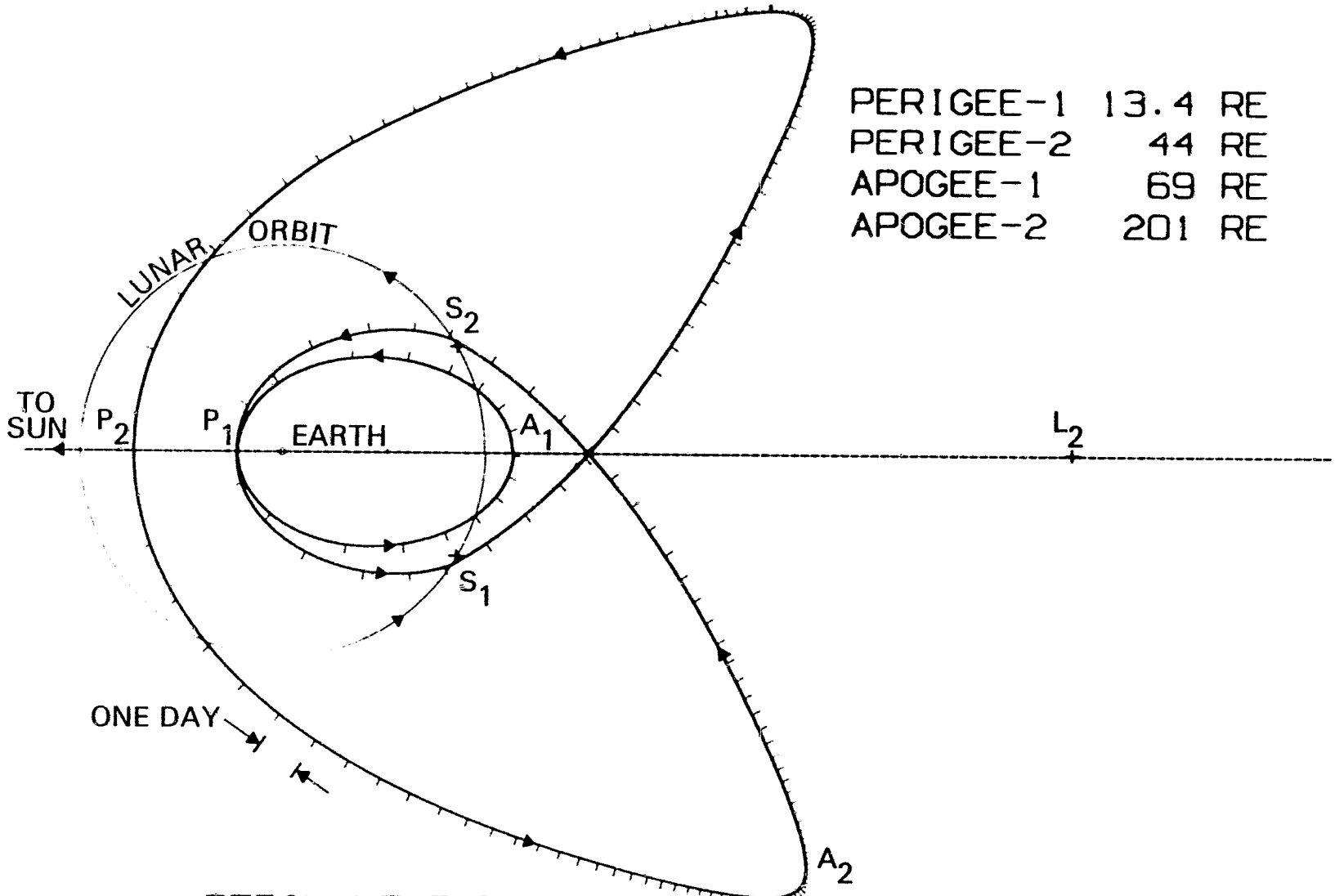


Figure 3-37. DOUBLE LUNAR SWINGBY ORBIT - [1,1,5,1] CLASS

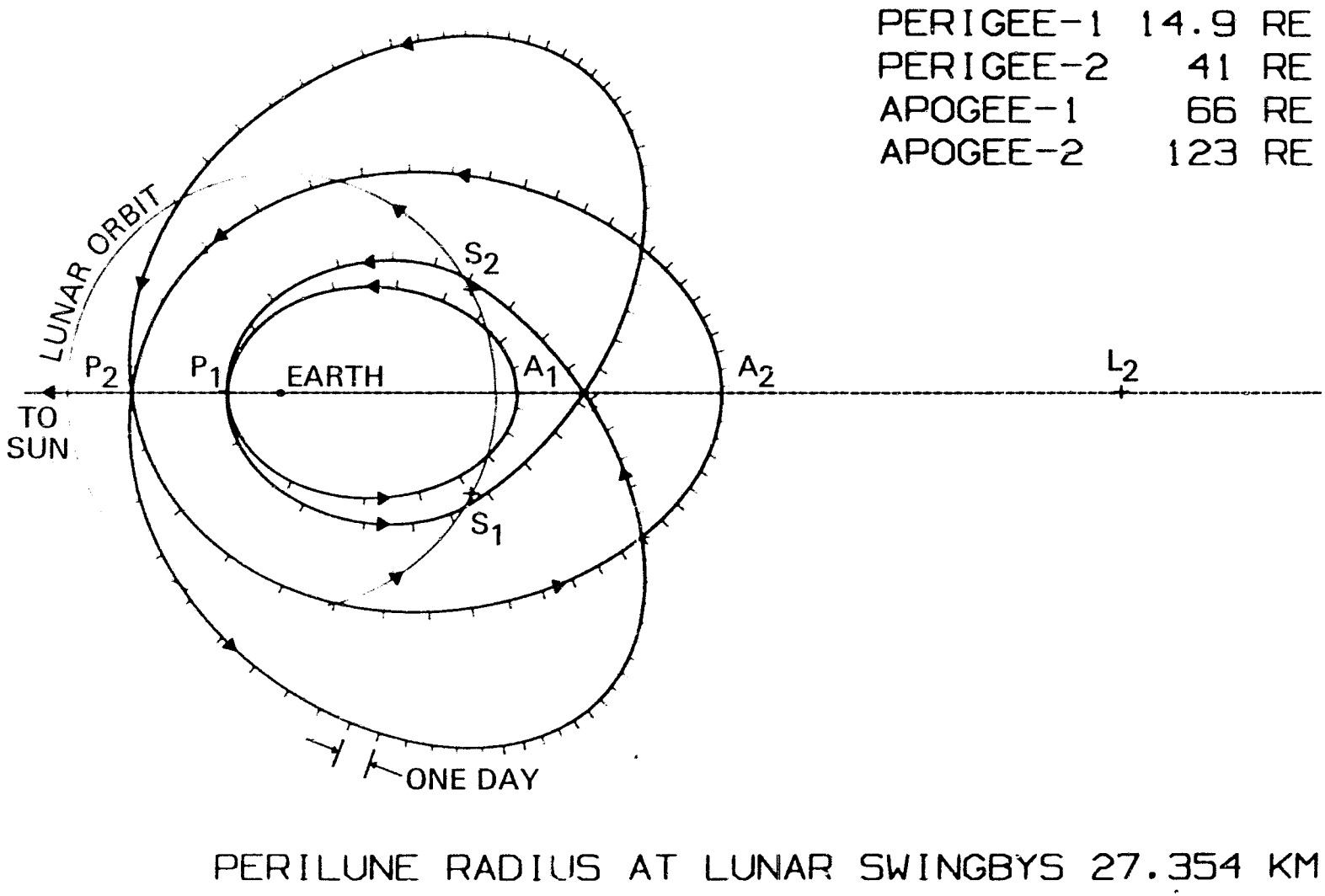


Figure 3-38. DOUBLE LUNAR SWINGBY ORBIT - [1,1,4,2] CLASS

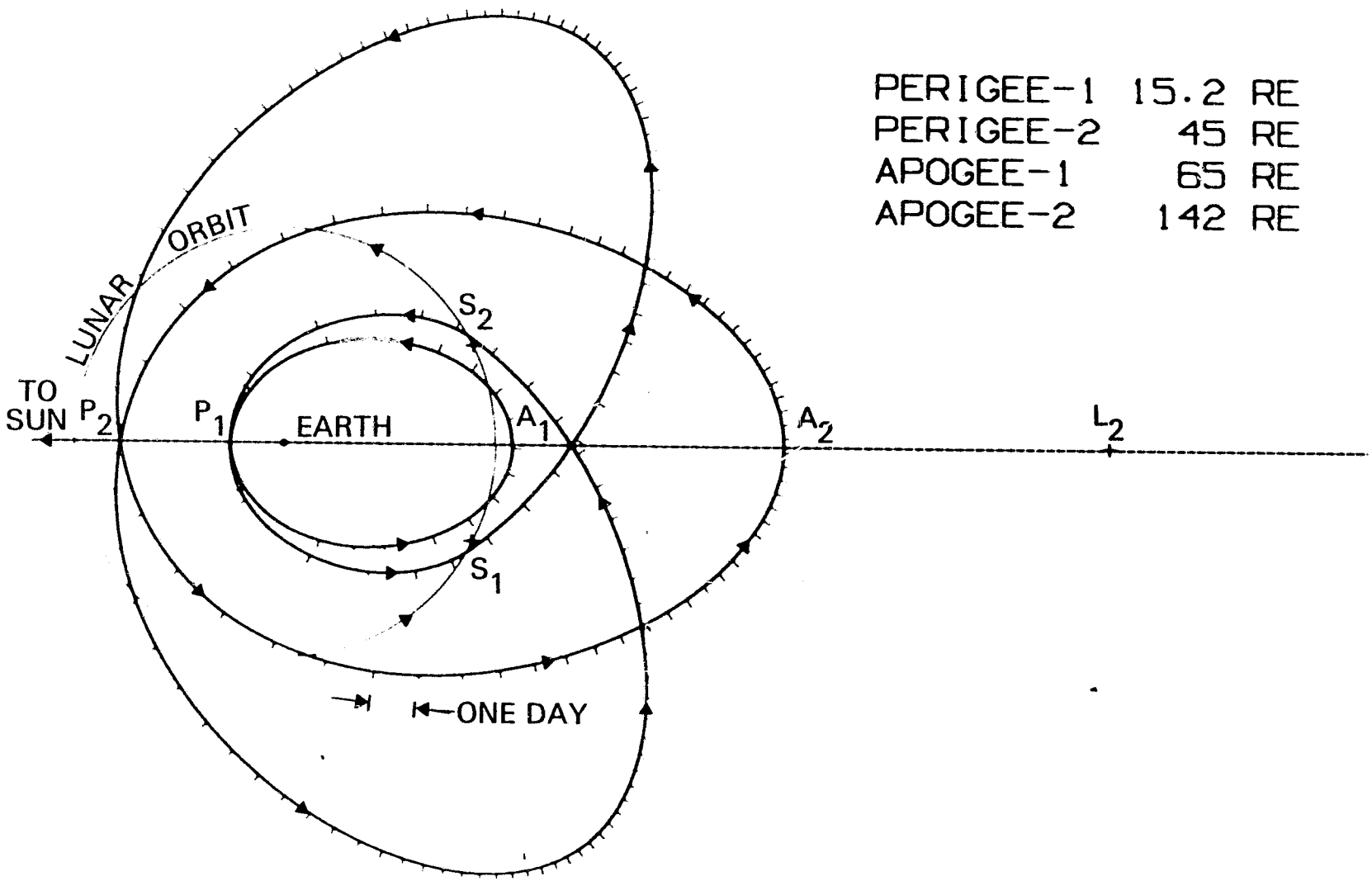
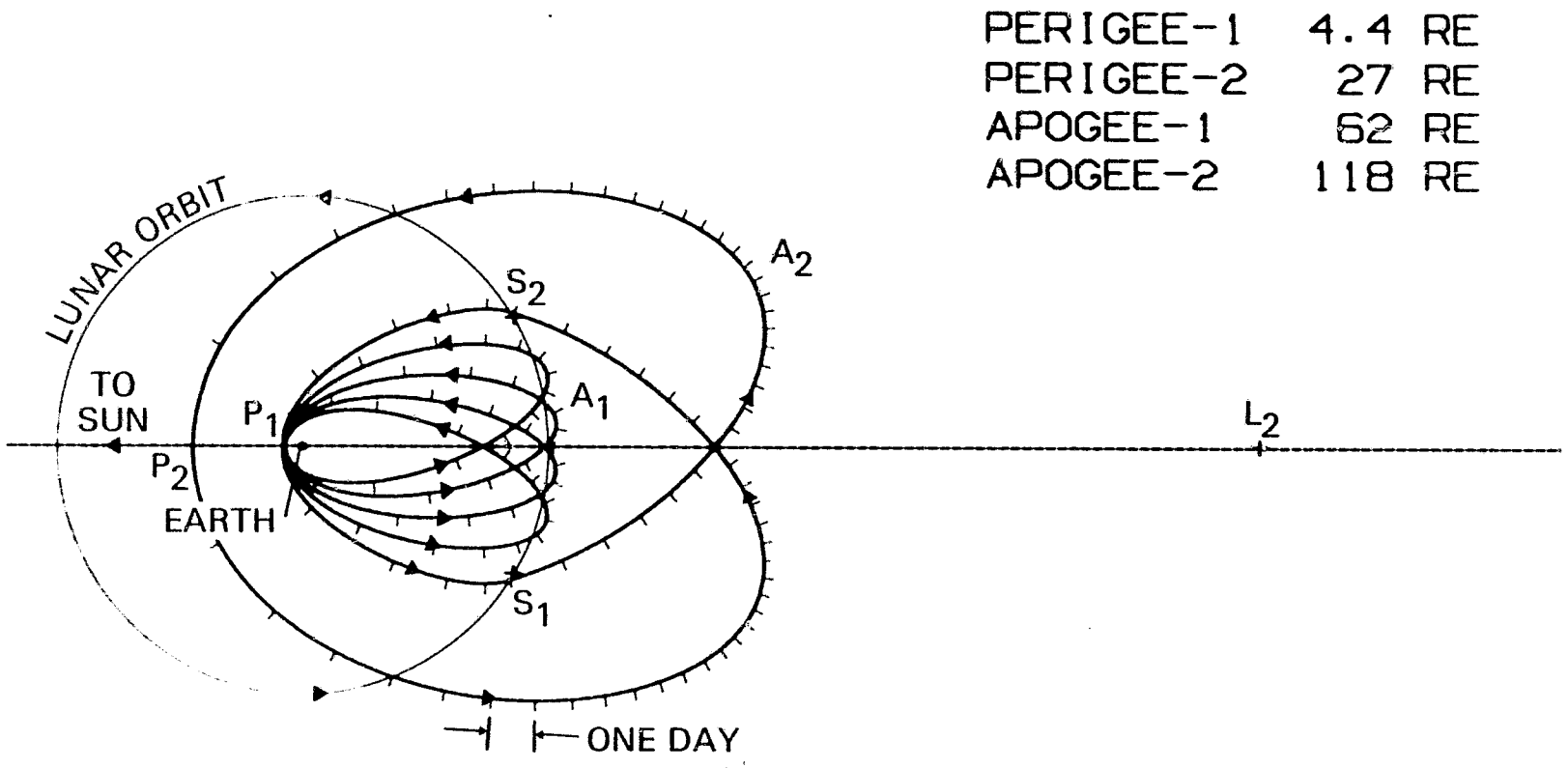
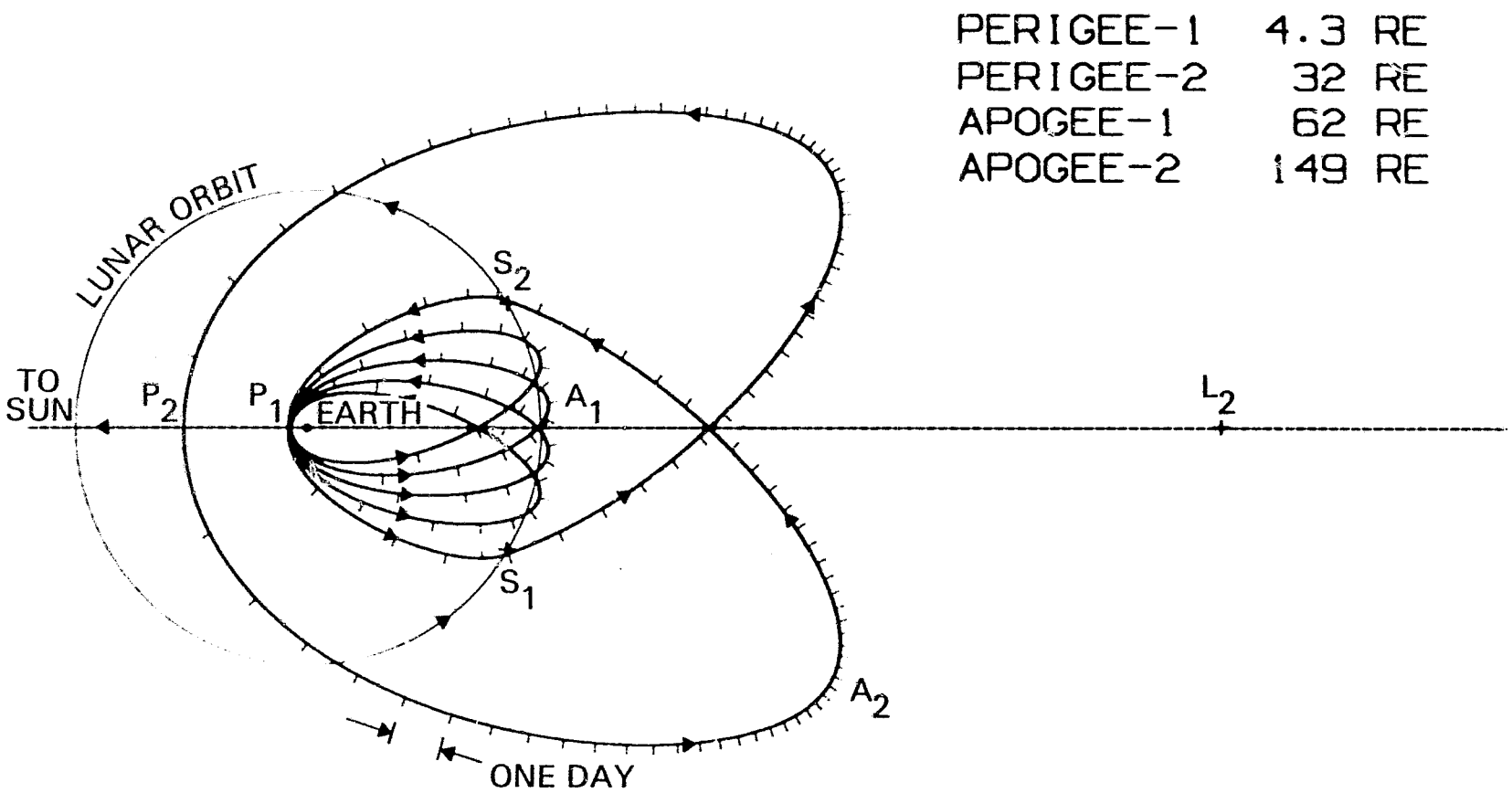


Figure 3-39. DOUBLE LUNAR SWINGBY ORBIT - [1,1,5,2] CLASS



PERILUNE RADIUS AT LUNAR SWINGBYS 11.448 KM

Figure 3-40. DOUBLE LUNAR SWINGBY ORBIT - [2,4,2,1] CLASS



PERILUNE RADIUS AT LUNAR SWINGBYS 9.195 KM

Figure 3-41. DOUBLE LUNAR SWINGBY ORBIT - [2,4,3,1] CLASS

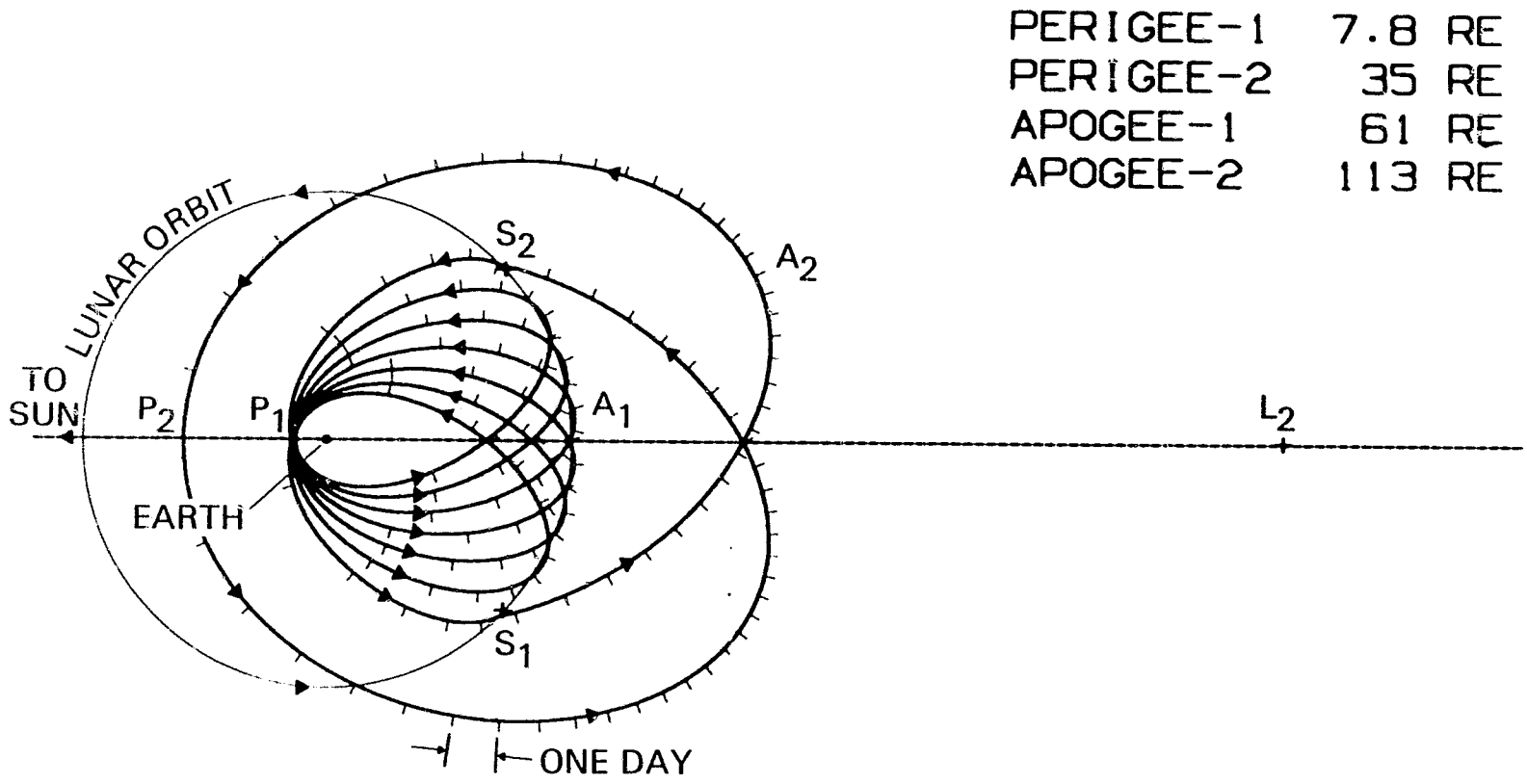


Figure 3-42. DOUBLE LUNAR SWINGBY ORBIT - [3,6,2,1] CLASS

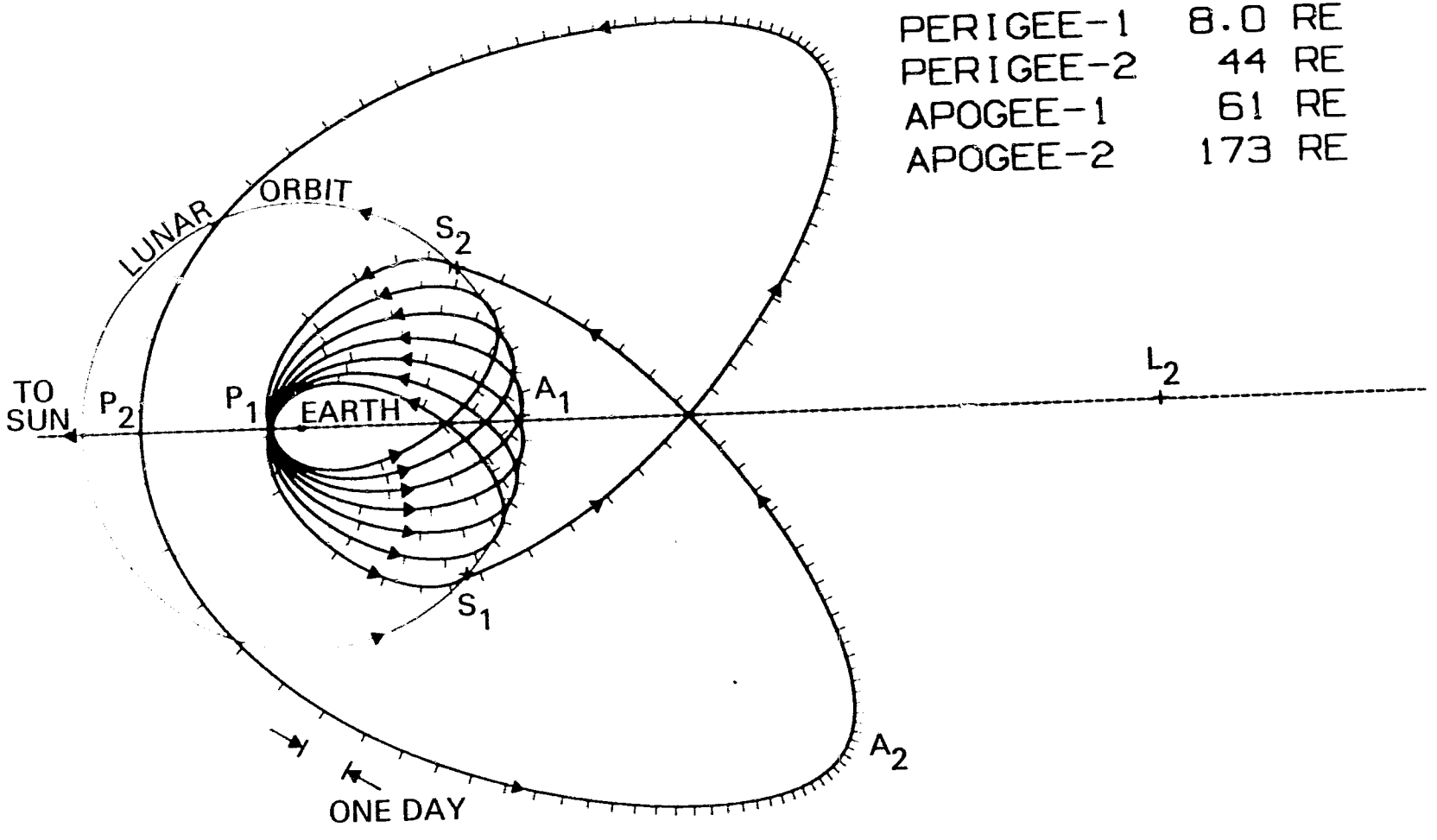


Figure 3-43. DOUBLE LUNAR SWINGBY ORBIT - [3,6,4,1] CLASS

REFERENCES

1. R. W. Farquhar and D. W. Dunham, "A New Trajectory Concept for Exploring the Earth's Geomagnetic Tail," A.I.A.A. Paper 80-0112 presented at the 18th Aerospace Sciences Meeting, Pasadena, California, January 14-16, 1980.

2. C. Uphoff, P. M. Roberts, and L. D. Friedman, "Orbit Design Concepts for Jupiter Orbiter Missions," Journal of Spacecraft and Rockets 13, 348 (1976).

3. S. A. Davis, "User's Guide for the Cinematic Trajectory Plots for the OPEN Program," CSC/TM-80/6217, August 1980.